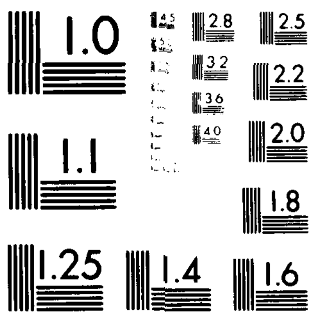
AD-A094 195 MITRE CORP MCLEAN VA METREK DIV F/G 1/5
AUTOMATIC TRAFFIC ADVISORY AND RESOLUTION SERVICE (ATARS) MULTI--ETC(U)
OCT 80 R H LENTZ, W D LOVE, N S MALTHOUSE DOT-FA80WA-4370
UNCLASSIFIED MTR-80W00100-REV-1 FAA-RD-80-3-REV-1 NL

1 OF 6
AD A
094195



MICROCOPY RESOLUTION TEST CHART

Report No. FAA-RD-80-3, Rev. 1

MTR-80W00100, Rev. 1

AUTOMATIC TRAFFIC ADVISORY AND RESOLUTION SERVICE (ATARS) MULTI-SITE ALGORITHMS

R.H. Lentz
W.D. Love
N.S. Malthouse
D.L. Roberts
T.L. Signore
R.A. Tornese
A.D. Zeitlin

The MITRE Corporation
Metrek Division
McLean, Virginia 22102

OCTOBER 1980

Document is available to the public through the
National Technical Information Service,
Springfield, Virginia 22161

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE
Washington, D.C. 20590

NOTICE

Technical Report Documentation Page

1. Report No. 19 18 FAA-RD-80-3 Rev 1	2. Government Accession No. AD-A094 195	3. Recipient's Catalog No.
4. Title and Subtitle 6 Automatic Traffic Advisory and Resolution Service (ATARS) Multi-Site Algorithms. Revision 1,		5. Report Date 11 October 1980
		6. Performing Organization Code
7. Author(s) 10 R.H. Lentz, W.D. Love, N.S. Malthouse, D.L. Roberts, T.L. Signore, R.A. Tornese, A.D. Zeitlin		8. Performing Organization Report No. 14 MTR-80W00100 Rev 1
9. Performing Organization Name and Address The MITRE Corporation Metrek Division 1820 Dolley Madison Boulevard McLean, Virginia 22102 12 505		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. 15 DOT-FA80WA-4370
12. Sponsoring Agency Name and Address U. S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D. C. 20590		13. Type of Report and Period Covered
		14. Sponsoring Agency Code ARD-240

15. Supplementary Notes

16. Abstract

This document presents detailed computer algorithms for programming the Automatic Traffic Advisory and Resolution Service (ATARS), formerly known as IPC, within a multi-site Discrete Address Beacon System (DABS) network. This document is to be used by Federal Aviation Administration to specify and define the ATARS portion of the integrated DABS/ATARS system.

The FAA has directed that the Conflict Indicator Register (CIR) be replaced by the Resolution Advisory Register (RAR) as the avionics mechanism for coordinating resolution advisories between ATARS sites and between ATARS and BCAS. Since it will be some time before the RAR can be fully incorporated into the ATARS algorithms, a number of modifications have been made to the ATARS logic which will permit testing of the rest of the ATARS design, while eliminating the special CIR message requirements, now obsolete, upon the DABS sensor. These modifications constitute Revision 1 to the original MITRE technical report on the ATARS multi-site algorithms.

17. Key Words	18. Distribution Statement
Collision Avoidance, Aircraft Separation Assurance, Traffic Advisory Service.	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	501	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

09870

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

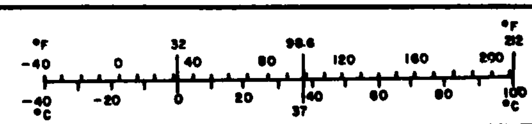


TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Concluded)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

<u>LIST OF ILLUSTRATIONS</u>
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

<u>LIST OF ILLUSTRATIONS</u>
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

TABLES

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

<u>LIST OF ILLUSTRATIONS</u>
(Continued)

LIST OF ILLUSTRATIONS
(Concluded)

FOREWORD

The FAA has directed that the Conflict Indicator Register (CIR) be replaced by the Resolution Advisory Register (RAR) as the avionics mechanism for coordinating resolution advisories between ATARS sites and between ATARS and BCAS. Since it will be some time before the RAR can be fully incorporated into the ATARS algorithms, a number of modifications have been made to the ATARS logic which will permit testing of the rest of the ATARS design, while eliminating the special CIR message requirements, now obsolete, upon the DABS sensor. These modifications constitute Revision 1 to the original MITRE technical report on the ATARS multi-site algorithms.

The following assumptions and requirements apply to the use of Revision 1:

(1) The uplink of resolution advisory messages will still be performed as originally specified using the CIR format. No resolution advisories will be updated on the display unless all resolution advisory messages are correctly received on that scan. Multiple resolution advisories will be processed by the avionics in the order specified by the ground system.

(2) No CIR rows will be downlinked by the sensor; the CIR Buffer will not be used as a direct interface between DABS and ATARS.

(3) No coordination will take place between ATARS and BCAS; hence, it is assumed that no aircraft will be equipped with BCAS.

(4) All adjacent ATARS sites will be connected by ground lines; coordination of resolution advisories between sites will be performed only over the ground lines.

(5) Site ID bits will be downlinked with each surveillance reply.

The primary objective in Revision 1 is to compensate for the lack of the CIR downlink. The basic technique used for this purpose is to create a "dummy" CIR, whenever it is needed, for each DABS aircraft receiving local service. In order to resolve timing difficulties with this approach, the processing of site ID bits has been moved to the Report Processing Task. To ensure the timely deletion of conflict table data for seam pairs for which a neighboring site has been responsible, a special

conflict table request message has been defined, and the Backup Mode Initiation Routine has been modified. Also, logic has been added to the delayed Master Resolution Task to ensure proper assignment of site responsibility for DABS-ATCRBS seam pairs. The text of this document has been left unchanged; the Revision 1 modifications have been documented by changes to figures and tables only. These changes are described in more detail in the following paragraphs.

The dummy CIR is created and placed in the CIR Buffer on a per-aircraft basis by the Uplink Delivery Notice Processing Routine (Figure 5-2), during non-surveillance processing, whenever one or more uplink delivery notices are returned for resolution advisory messages. Therefore, CIR processing will only take place when the uplink of resolution advisories to an aircraft is being attempted. The dummy CIR consists of the delivery notice for each uplinked resolution advisory and a "CIR empty" message. The updating of the GEOG variable from the site ID bits is now performed by the Report Processing Task (Figure 4-3) instead of by the CIR Processing Task (Figure 5-4). A four-bit field has been added to the DABS report format for the site ID bits. (See Table 3-3.) The effect of these changes upon task sequencing and timing is shown in Figure 3-1 and Table 3-1.

The flow chart for the CIR Processing Task (Figure 5-4) has been further modified to issue a request for remote CIR data whenever the exchange of messages with the CIR has been unsuccessful because of data link failure. This procedure is already described in the text (Section 12.3), but was not explicitly shown in the flow chart. With a non-CIR DABS sensor, this feature enables the local site to request help in delivering resolution advisory messages from a neighboring site. In this case, the remote site's CIR Remote Processing Routine will return to the local CIR Buffer a dummy CIR containing uplink delivery notices for those resolution advisory messages generated by the local site.

The CIR Processing Task (Figure 5-4) has also been modified so that the External Pair Deletion Routine and the External Pair Updating Routine are no longer called when the CIR is empty. Instead, a special conflict table request message is used to delete external pairs for which another site is responsible. Two new one-bit fields have been added to the conflict table request message for this purpose. (See Table 12-2.) This special message is sent by the Pair Record Deletion Routine (Figure 13-2) whenever it deletes a pair record for a seam conflict for which the local site had assumed resolution

responsibility (i.e., ATSID = own ID). The Incoming Seam Pair Request Processing and Reply Task (Figure 12-3) at the receiving site then deletes the pair record, if any, for the pair.

Changes have been made to the Internal Pair Updating Routine (Figure 5-10) relating to handoff messages. The successful delivery of a handoff message is recorded by the Internal Pair Updating Routine in all cases by resetting the SEND flag for the aircraft and setting the resolution advisory to null in the conflict table. When all handoff messages have been successfully received, the pair record can be deleted.

An addition has been made at the beginning of the Master Resolution Task (Figure 9-3) for delayed resolution. This addition helps to ensure the proper assignment of site responsibility for resolving DABS-ATCRBS conflicts in seam areas. In this case, a potential problem arises when two sites attempt to assume responsibility simultaneously for a DABS-ATCRBS pair. Each site sends a message to the other, and the two messages in effect "pass" each other on the ground lines. Previously, the CIR row IDs and the CIR downlink were used to resolve this problem. Without the CIR downlink, the problem recurs. The new logic added to delayed master resolution enables both sites to recognize this situation (by finding an existing pair record with ATSID not equal to own ID) and to apply a site-ID priority test to break the tie.

Finally, logic has been added to the Backup Mode Initiation Routine (Figure 15-2) to ensure the proper disposal of conflict data for seam conflicts resolved by a failed site. This new logic permits the local site to quickly assume responsibility for such a conflict where possible and to delete the pair record otherwise. When the local site is capable of taking over (i.e., both aircraft are in the local service area), PWISF and the handoff bit in ATSID are set, and POSCMD is set to -1. This allows the local site, if it detects the conflict, to take over and choose compatible resolution advisories on the next scan. If the local site does not detect the conflict (i.e., CMDFLG is not set), then the pair record will soon be deleted by the Conflict Pair Removal Task.

It should be pointed out that, since the CIR will always be considered empty in Revision 1, certain routines will never be called by the CIR Processing Task. These include:

(1) CIR Threat Correlation Routine

(2) External Pair Deletion Routine

(3) External Pair Updating Routine

(4) CIR ATCRBS Correlation Routine

(5) Update Sector ID Routine

Note, however, that the last two of these routines are used by other tasks. ATCRBS correlation must be performed by the Incoming Seam Pair Request Processing and Reply Task, while the Update Sector ID Routine is used by the Conflict Pair Removal Task.

Because of the Revision 1 modifications to this document, certain parts of Section 15, "Failure Mode Operation," are no longer accurate. Section 15.4, "Incomplete CIR Downlink Report," is obsolete; the CIR downlink can no longer fail. However, it is still true that CIR processing will only be performed for an aircraft if a successful uplink delivery notice has been returned for each resolution advisory which was to be uplinked. Section 15.5, "ATARS Selects Incompatible Resolution Advisory," is also obsolete. With Revision 1, ATARS is assumed to obtain, via ground lines, all information needed to pick compatible resolution advisories. Since no CIR is actually downlinked and the dummy CIR is always declared to be empty, the CIR Processing Task will always find the resolution advisories chosen by the local site to be compatible and will never force their recomputation. Section 15.6, "Failure of Ground Communications Channel," is partly in error. Without the CIR downlink, a ground communications channel between sensors becomes a critical element for ATARS operation. The loss of a ground line could result in duplicate or conflicting advisories being received by an aircraft in a seam area.

The modifications to the ATARS algorithms described above should allow both single site and multi-site operation to proceed in a normal manner with a non-CIR DABS sensor. Although no coordination with BCAS can take place, full site-to-site coordination of resolution advisories can be achieved via ground lines.

1. INTRODUCTION

The purpose of this document is to specify the computer algorithms and operation of the Automatic Traffic Advisory and Resolution Service (ATARS) and its interface with the Discrete Address Beacon System (DABS). Reference 1 describes the DABS sensor which provides surveillance and communications to permit operation of the ATARS function.

This document provides algorithm specifications for the following:

1. report processing and tracking logic,

2. conflict detection and resolution logic,

3. a traffic advisory service,

4. logic to permit operation in a multi-site environment,

5. logic to interface with the Beacon Collision Avoidance System (BCAS),

6. logic to treat various failure conditions.

It does not, however, specify ATARS procedures to be followed or standards to be met in supplying the ATARS function. This subject is treated in Reference 1 and the ATARS function to be supplied is subject to all of the requirements of Reference 1 as if this document were incorporated in total at the point of reference.

Reference 2, which provides a broad conceptual-level description of ATARS, is a useful document for describing the philosophy and goals of the ATARS function in detail.

Reference 3 provides a detailed description of the DABS/ATARS function in the context of the Air Traffic Control (ATC) operational environment.

Certain conventions and definitions of terms used in writing this document need to be explained.

Three terms are used in discussing the facilities at a particular location. The term sensor means the complete DABS sensor as described in Reference 1. The term ATARS function refers to all of the additional hardware and software required at a location to provide ATARS service. The ATARS function is

described by this document. In this document the term, ATARS function, is frequently used as if it were describing a separate piece of physical equipment. However, the implementation of ATARS may not be done in physically separable hardware and so this term must be looked on as referring to a conceptually separate function or task. The third term, site, refers to the DABS sensor and ATARS function at a single location, collectively. Any of these three terms may be qualified by the terms local and remote. Local refers to an item at a single location of principal concern. Remote refers to an item at any other location.

The term advisory is used to refer to a message to be delivered to an aircraft. There are several types of advisory messages generated by ATARS.

The term scan refers to the act of the sensor antenna rotating through one complete revolution, or to the time required for this act to take place.

Several terms are used to describe the DABS and collision avoidance avionics equipage of an aircraft and the distinctions between these terms need to be understood. An aircraft can be classified as radar only (non-beacon) or as ATCRBS (Air Traffic Control Radar Beacon System) or DABS depending on the type of beacon transponder carried by the aircraft. An aircraft can also be classified as either ATARS equipped or unequipped depending on whether or not that aircraft has an ATARS display. This classification is used to select appropriate collision avoidance advisories for a given pair of aircraft. An ATCRBS aircraft and radar only aircraft are always designated as unequipped. However, a DABS aircraft may be either ATARS equipped, BCAS and ATARS equipped, or neither (unequipped).

In the flow charts, the invocation of a separate routine is indicated by putting the name of the routine as the first line of a block which is set off by a horizontal line drawn completely across the block. The name is followed by a brief description of the tasks being performed by the routine. With the exception of the routine call block the flow chart symbology conforms to the standards specified in Reference 4.

State vector variables which are subscripted with "next" are local variables which are used in cases where both the updated and original values of the variable are needed during intermediate calculations or in cases where it may not be clear whether updated or original values are to be used. They should not be confused with the state vector variable of the same name. In most cases these variables are used to update the state vector

field of the same name immediately upon determination of their value. Where this is not the case they must be temporarily stored. These local variables are passed between routines and at the appropriate time are used to update the state vector. The text and detailed flow charts make it clear when the local variables are used to update the state vector.

Section 2 is a brief overview of the ATARS concept describing the services provided by the ATARS algorithms. This section is for familiarization only and is not a complete system description.

Section 3 provides a high-level view of the operation of the ATARS elements and discusses the coordination between them. It also describes the external interfaces of the ATARS function.

Section 4 provides detailed description and flow charts for the report and tracking tasks.

Sections 5 through 14 contain detailed descriptions and flow charts for the aircraft processing, conflict detection, conflict resolution, BCAS coordination, and multi-site coordination function of the ATARS system.

Section 15 provides detailed flow charts and a description of the algorithms to be implemented under various failure conditions of the DABS/ATARS system.

Appendix A collects all of the ATARS system parameters and presents nominal values for each of them.

Appendix B is an alphabetical list of all abbreviations used in the flow charts. When one abbreviation is used for different words the intended meaning is clear from the context of the flow chart.

2. SYSTEM OVERVIEW

The basic concept of ATARS is very briefly reviewed here as background to the technical description of the algorithms. A complete functional description is presented in Reference 2. The discussion here is only intended to introduce ATARS to the program designer.

2.1 Summary Concept Description

The Automatic Traffic Advisory and Resolution Service is a ground based collision avoidance system to be implemented in the following environment:

1. full X, Y, and Z (altitude reporting) surveillance or non-Mode C (Mode A or primary data) on all aircraft in the ATARS surveillance area,

2. direct digital data link to displays in the cockpits of aircraft receiving ATARS service,

3. aircraft with a Beacon Collision Avoidance System (BCAS) operational (see Reference 5),

4. netted and non-netted adjacent DABS sites,

5. an automated decision process.

The Discrete Address Beacon System (DABS) provides the fully automatic surveillance and data-link communications capabilities which are prerequisite to the realization of ATARS.

The ATARS system monitors the location, altitude, and velocity of all aircraft throughout a contiguous airspace via the surveillance capability. A ground based computer processes the data and continuously provides proximity warning information and, when necessary, resolution advisories to aircraft receiving ATARS service. A limited traffic advisory service is provided to inform ATARS equipped aircraft of nearby non-Mode C aircraft. Certain messages are generated by ATARS and displayed to the responsible air traffic controller at the ATC facility when a conflict involving a controlled aircraft is detected by the ATARS system.

2.2 Types of Encounters

The ATARS system behaves differently depending on whether the aircraft in conflict are under control of the ATC system

(controlled aircraft) or not (uncontrolled aircraft), and on whether or not one aircraft is unequipped to receive ATARS resolution advisories or has not adequately responded to the original resolution advisory. The types of messages to be sent to the aircraft and the parameters used in the detection algorithms vary with the type of encounter involved.

2.2.1 Uncontrolled/Uncontrolled

ATARS is a limited form of ground-based air traffic control which provides proximity warning and separation services to uncontrolled aircraft in a given region of airspace. It is intermittent in that it intervenes into the VFR (Visual Flight Rule) flight regime only when that flight's present course and altitude put it in conflict with other traffic. It does not require the pilot to file a flight plan or to operate under an ATC clearance.

The lookahead times and minimum miss distance criteria used for uncontrolled/uncontrolled conflicts are of a "tactical" nature (e.g., 30 seconds and 0.5 nmi) and imply intervention only when a conflict is imminent. The uncontrolled aircraft still operates in a primarily "free flight" mode.

2.2.2 Uncontrolled/Controlled

In an uncontrolled/controlled encounter, the air traffic controller becomes another element in the resolution of a conflict. The sequence of events is as follows. At a tau value (relative range/relative range rate) on the order of 40 seconds to a violation of 1.2 nmi. horizontal separation or 375 feet vertical separation, a Controller Alert Message is generated and displayed to the controller with responsibility for the controlled aircraft. This message will contain the conflict resolution advisory which ATARS would deliver to the uncontrolled aircraft. At the same time a threat advisory is issued to both pilots indicating that a conflict is imminent and that they should initiate evasive action as required. (If the conflict alert messages which are generated within the en route or terminal automation systems are already displayed for this aircraft pair, the controller message generated by ATARS will not be displayed in duplicate.) The controller observes the warning on his display and may elect to maneuver the controlled aircraft to avoid the uncontrolled aircraft or simply issue an advisory on the traffic. If no action is taken, at about 15 seconds later a resolution advisory is issued to the uncontrolled pilot informing him that he should perform the evasive maneuver indicated. If it is determined that the conflict situation has continued to

deteriorate (tau reaches approximately 25 seconds) then the controlled aircraft is issued a resolution advisory.

2.2.3 Controlled/Controlled Encounters

ATARS will serve a role as a back-up blunder detection system for conflicts between two controlled aircraft in the same sense as the present conflict alert functions in the terminal and en route automation systems. However, it is not intended to supplant the ATC system or routinely issue resolution advisories to controlled aircraft.

The continued execution of ATARS with direct data link commands to controlled aircraft as well as uncontrolled aircraft can be a significant transient backup during catastrophic ATC facility failure. The controlled pilot routinely receives an ATC system failure clearance which he is expected to follow in the event of system failure, with the ATARS system providing an additional emergency collision avoidance function.

A Controller Alert Message is generated by ATARS at a suitable warning time and, if not overriden by a Conflict Alert Message generated within the ATC facility, is displayed to the responsible controller. This message contains the conflict resolution advisories for both aircraft which ATARS would issue. Both pilots are informed that a threat is imminent. If no action is taken to resolve the conflict, ATARS will issue resolution advisories to the pilots about 20 seconds later.

2.2.4 Encounters With More Than Two Aircraft

Logic has been developed to resolve conflicts involving more than two aircraft. Details of this logic are presented in a later section.

2.2.5 Encounters With One Aircraft Unequipped

The ATARS system can detect conflicts between one equipped aircraft and one aircraft which is unequipped. The system uses longer lookahead times so that the conflict can be satisfactorily resolved by issuing resolution advisories only to the equipped aircraft.

2.2.6 Encounters Which Are Not Resolved With Initial Resolution Advisory

Special logic to alter the resolution advisories is implemented in encounters which continue to deteriorate after initial

advisories have been issued. When these are detected an additional advisory may be issued to one or both aircraft.

2.3 Uplink Message to be Sent to Aircraft

Behavior of the ATARS system revolves around the cockpit display which determines the form of possible ATARS messages. The ATARS uplink messages have been specified to allow a wide variety of display implementation.

2.3.1 Proximity Advisory

A Proximity Advisory Message is used to inform a pilot of the presence of nearby proximate aircraft. The message contains sufficient information to indicate the bearing, relative altitude, and heading of the other aircraft. The horizontal ranges and altitude zones that determine when a proximity advisory will be issued vary with the performance of the aircraft involved. If one aircraft receives an advisory because of the proximity of a second aircraft, that second aircraft (if ATARS equipped) will also be issued an appropriate advisory indicating the presence of the first aircraft. Note that for all ATARS service, at least one aircraft must be data link equipped.

2.3.2 Threat Advisory

When an aircraft is in an encounter for which tau is less than some threshold but is not yet so low as to require a resolution advisory, a Threat Advisory Message is issued to warn the pilot of the potential collision situation. This message is given approximately 15 seconds or more in advance of the resolution advisory to give the pilots involved time to resolve the conflict on their own by locating each other visually using the relative bearing, altitude, and heading data from the Threat Advisory Message.

2.3.3 Negative Resolution Advisory

The pilot will be given a negative resolution advisory when his aircraft's rate of closure with another neighboring aircraft is sufficiently high but the issuance of negative advisories will provide sufficient separation to resolve the conflict. These advisories are in the form of generic "don't" messages ("don't turn left", "don't climb", etc.). Sufficient information is provided in the uplink message to provide the pilot with bearing, altitude, heading, etc. of the threat.

One type of negative resolution advisory indicates that a maneuver in a particular direction could be hazardous, but that the present heading and altitude are satisfactory. The Vertical Speed Limit (VSL) is another type of negative advisory which would require that the pilot limit his rate of climb or descent to avoid a nearby aircraft.

2.3.4 Positive Resolution Advisory

A positive resolution advisory will be issued whenever it is determined, based upon a constant velocity projection of the aircraft, that the aircraft will come within some minimum horizontal miss distance at any time from the present up to and including some look-ahead time and whenever a negative advisory will not provide adequate separation. In conjunction with the issuance of a positive advisory, additional information is available to present the position, velocity, altitude, and other information on the threatening aircraft.

Resolution is accomplished by selecting the best maneuver for each aircraft for the particular geometry such that clearance of the hazardous approach will be provided. This is accomplished by modeling each aircraft in all possible maneuvers and selecting the one which provides the greatest degree of safety based on the consideration of many factors. The advisories are removed when the aircraft no longer satisfy the detection criteria for such advisories.

2.3.5 Own Message

The ATARS ground based system will when required provide an Own Message to equipped aircraft. This message will contain relevant information to own aircraft such as tracked heading, ground speed, altitude, and turn rate. This information is used by the aircraft's on board display processor to aid in the presentation of ATARS generated advisories.

2.3.6 Terrain, Airspace, and Obstacle Avoidance Messages

ATARS will provide an alert to pilots when a violation of restricted airspace is imminent. Uncontrolled aircraft will be alerted upon entry into the Terminal Control Area (TCA). An alert will be given if an aircraft is too near the terrain or an obstacle. A map of the terrain in the ATARS service area will be generated from U. S. Geological Survey Data and provided for access by the ATARS processor. Obstacles and restricted airspace regions will also be stored for access by ATARS.

2.4 Multi-site Considerations

ATARS is to be implemented in a complete system by performing the ATARS function in the same digital computer facility that is resident at each DABS sensor site. Hence, ATARS is implemented as a distributed function and must be provided with a means for coordination between adjacent ATARS functions.

The necessary coordination between ATARS functions can be achieved by providing direct ground communications links between adjacent DABS sites or by using the information stored in the Conflict Indicator Register (CIR). This register is on board each aircraft which is equipped to receive ATARS service. Each ATARS function performs ATARS calculations for all aircraft within a specified geographical area which represents the area of responsibility of that ATARS. These areas of responsibility overlap in the vicinity of their boundaries to form seam areas in which two or three ATARS functions may have responsibility. The generation of incompatible resolution advisories to a pair of aircraft by two different ATARS functions is prevented by assigning a priority ordering to sites which provide service in the seam between sites. The site which sees both the aircraft and has the highest priority is allowed to resolve the conflict.

2.5 ATARS - BCAS Coordination

The coordination of ATARS and BCAS is through the CIR. The CIR is a resolution advisory storage device on board each BCAS and ATARS equipped aircraft. This device is read by BCAS and DABS sensor interrogations. The current resolution advisories generated by either BCAS or ATARS are taken as constraints when either system selects maneuvers for a new conflict.

3. HIGH LEVEL PROCESSING

This section discusses the execution control, the sequencing of tasks, and the external interface of ATARS sector processing. The contents and general purpose of the Aircraft State Vector are explained, and the differences between the en route area operation and terminal area operation are discussed.

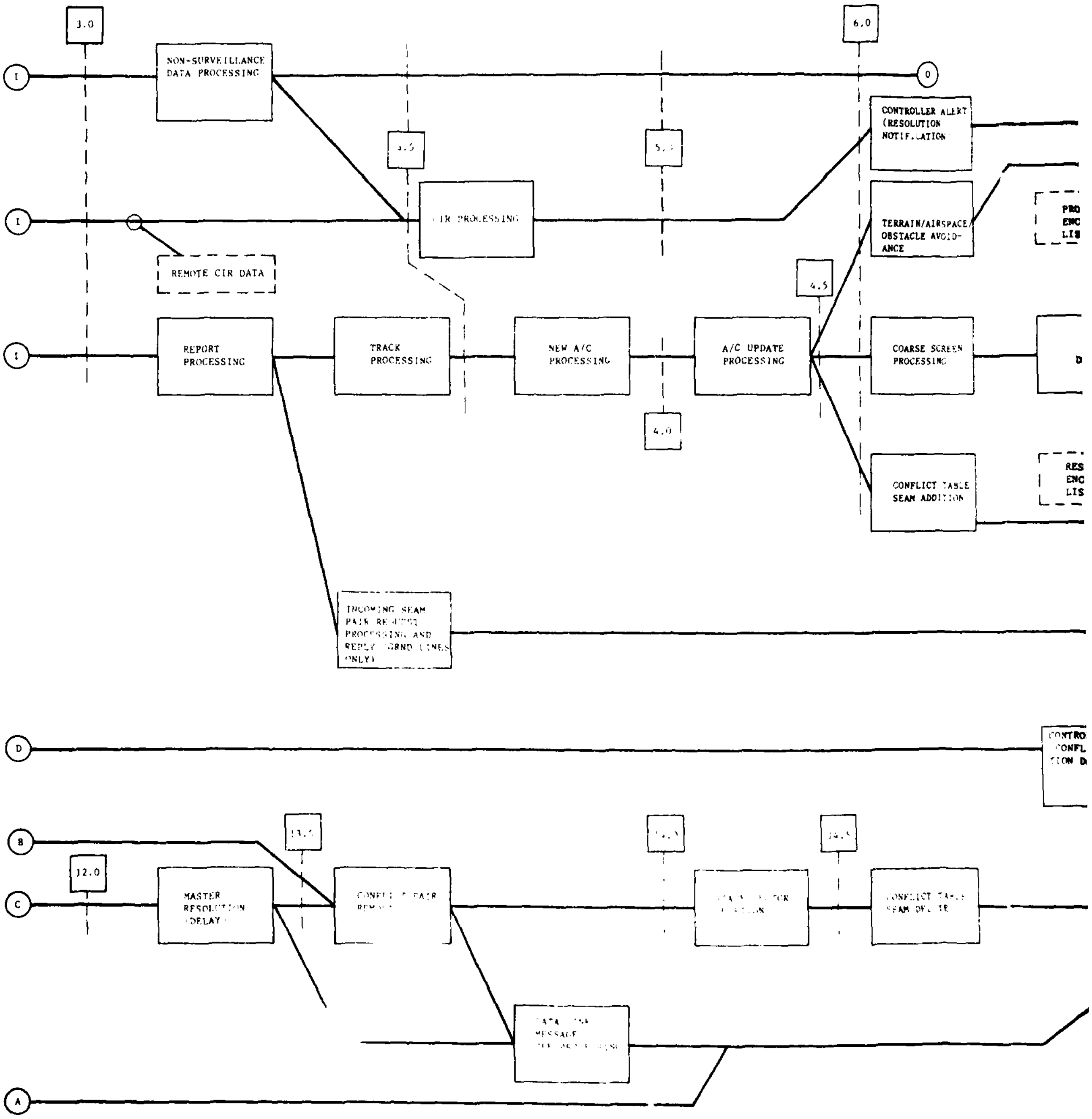
3.1 Execution and Timing

Special consideration must be given to the proper interplay and overall control of the sector oriented task sequencing of ATARS. Executive control must arrange for smooth transitions of control and effective utilization of computer time resources. Although a precise implementation of an executive program is not specifically addressed, a solution is outlined in the diagram of Figure 3-1.

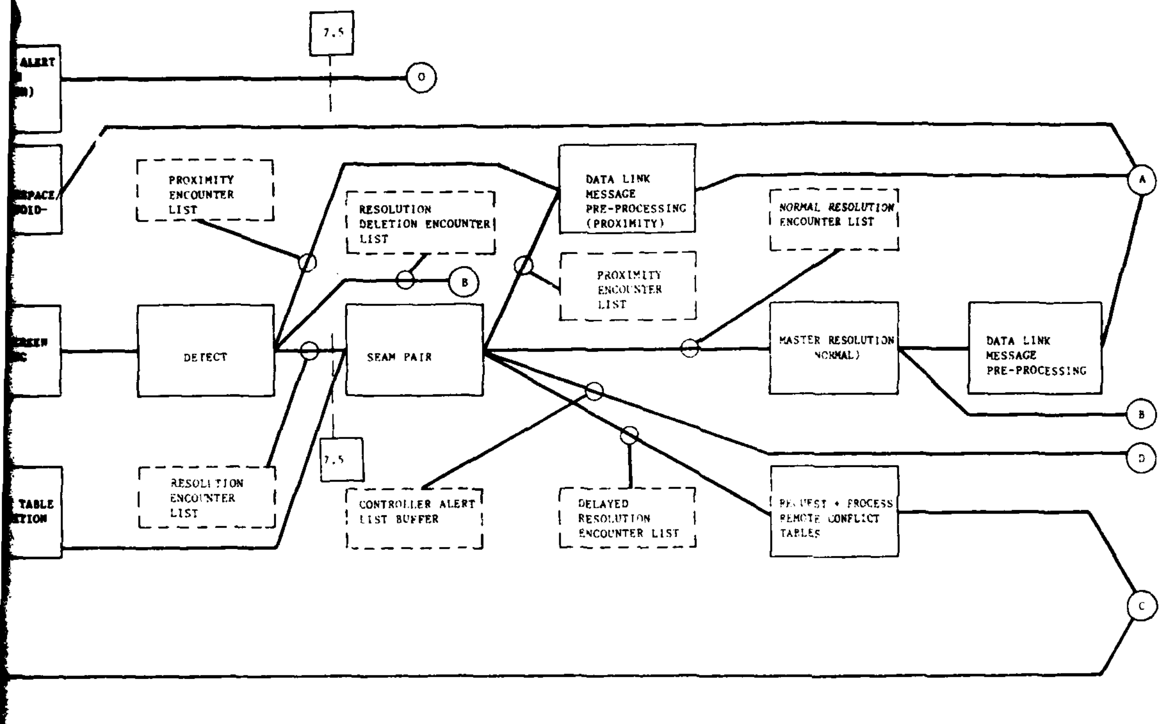
Sector processing in ATARS provides a method to take small, defined areas (sectors) of the ATARS surveillance area and process the data from each sector as a group. The ATARS sectors illustrated in Figure 3-1 contain two antenna sectors of 11 1/4 degrees each. Because of a generalized design approach for sector processing, the requirement for an ATARS sector to contain two antenna sectors is flexible and may be site adaptable. Care must be taken when enlarging the ATARS sectors in that a larger area would contain a larger data base and each sector would have to be processed in a shorter time. Also, certain sector and time dependent parameters need to be adjusted.

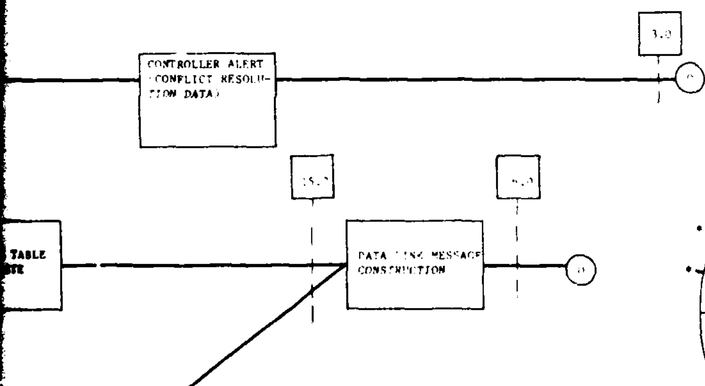
The report-to-track correlations provided by the DABS sensor are accepted by ATARS as they are received because ATARS is an uncorrelating user. Track data which is tranferred from DABS to ATARS is slaved to the antenna rotation. Target reports arrive in the buffer area in a batch (one sector's worth of reports) once per 11 1/4 degree antenna sector. The DABS sensor triggers the ATARS executive to read the report buffer which includes a header containing the sector identification and sector time.

The real-time processing rate of ATARS is maintained in synchronization with the DABS sensor beam. This antenna sector synchronization is important because the executive program must order tasks to be initiated and terminated for the ATARS sector's data at discrete times in the processing scan. These times, noted as critical times in Figure 3-1, refer to the start of a particular sector in the processing scan. (e.g., The first critical point noted is 3. This means no data for sector 1 is available for the Report Processing Task before the start of sector 3.) The



3.0
NON-SURVEILLANCE DATA PROCESSING
6.0
I
O
CONTROLLER ALERT (RESOLUTION NOTIFICATION)
REMOTE CIR DATA
TERRAIN/AIRSPACE OBSTACLE AVOID-ANCE
4.5
REPORT PROCESSING
TRACK PROCESSING
NEW A/C PROCESSING
A/C UPDATE PROCESSING
COARSE SCREEN PROCESSING
4.0
CONFLICT TABLE SEAM ADDITION
INCOMING SEAM
D
B
C
A
12.0
MASTER RESOLUTION (DELAY)



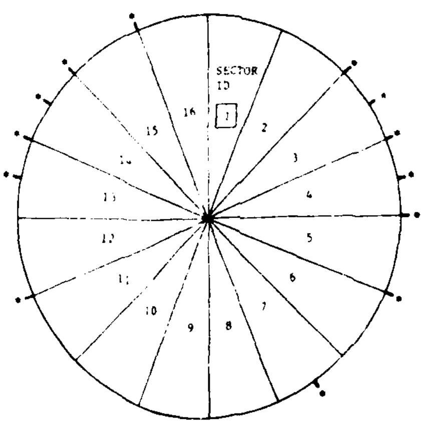


N INDICATES BEGINNING OF PARTICULAR ATARS SECTOR

[N] ALL SECTORS DATA MUST BE PROCESSED BEFORE NEXT MODULE MAY BE EXECUTED
NO DELAYED PROCESSING FOR SECTOR DATA AFTER THIS POINT IN TIME

I INPUT

O OUTPUT



• DENOTE CRITICAL POINTS IN TASK SEQUENCING (NOTED BY VERTICAL DOTTED LINES IN DIAGRAM) WHERE SEVERAL TASKS MUST BE COMPLETE BEFORE CONTINUING

FIGURE 3-1
SECTOR ORIENTED TASK SEQUENCING

sector numbers in the diagram illustrate the sequencing of tasks for the track data in sector 1, but are easily related to any sector by just adding the desired sector's identification number minus 1 to the critical point. (e.g., Critical point 3 on the diagram is the start of sector 3 when referencing the processing of sector 1 data. If sector 4 data is the reference, then critical point 3 on the diagram becomes 3 + (4-1), or sector 6.)

The sector processing diagram illustrates all the tasks that must be executed within one scan for each sector of data. The task sequencing and data flow are shown by the solid connecting lines. Each step in the process is dependent on one or more tasks being completed or an input buffer being filled. When two or more tasks must be completed for a new task to start, a critical point in sector processing is noted. A summary of the time span required or allowed for each task in a single scan is outlined in Table 3-1. The executive program controls the initiation and termination of each task according to the window length for each task. With the starting times and processing windows allowed for the various tasks, several tasks throughout the processing cycle may run in parallel while processing a particular sector. The executive determines that each sector is processed in a step-by-step manner throughout the ATARS process. At the same time, the executive program controls and determines when each task is ready to accept the next sector for processing as critical points are reached in the task sequencing. The executive program handles the major data structures (Table 3-2) for the tasks by providing pointers to each sector of data in the data structure and by placing data in the various structures. This keeps the data segregated according to sectors. Care must be taken by the executive to make sure that data structures and lists for a particular sector are not being updated and read at the same time. A mechanism for lockouts must be implemented to prevent this possibility.

One delay is required during the task sequencing and must be implemented by the executive. This delay is required to make sure that up-to-date aircraft positions and velocities are used when determining potential conflicts or resolving old conflicts with the sector being processed. This delay occurs after execution of the Aircraft Update Processing Task and the new position in the data base has been established for the aircraft in the sector. (The aircraft are ordered in the data base according to their X-coordinate in order to expedite processing in succeeding tasks.) In order to have current positions for aircraft in the two adjacent sectors, further processing of the current sector is delayed until aircraft in the next two sectors have been updated.

TABLE 3-1

TIMING WINDOWS FOR ATARS FUNCTIONAL PROCESSES

ATARS FUNCTION	WINDOW (SECTORS)	ATARS FUNCTION	WINDOW (SECTORS)
1. Downlink	N, N+1 (2)	14. Data Link Message Pre-processing (Proximity)	N+5, N+13 (9)
2. Surveillance RPT Process	N+2 (.5)	15. Seam Pair Test	N+6.5, N+10 (4.5)
3. Non-surveillance RPT Process	N+2 (.5)	16. Master Resolution (Normal)	N+6.5, N+12 (6.0)
4. Tracker	N+2 (.5)	17. Request and Process Remote Conflict Tables	N+6.5, N+10 (4.5)
5. CIR Processing	N+2, N+3 (1.5)	18. Controller Alert (Conflict Resolution Data)	N+6.5, N+1 (11.5)
6. Incoming Seam Pair Request Processing and Reply	N+2, N+10 (9)	19. Data Link Message Pre-processing	N+6.5, N+13 (7.5)
7. New A/C	N+2 (1.0)	20. Master Resolution (Delayed)	N+11, N+12 (1.5)
8. A/C Update	N+3 (0.5)	21. Data Link Message Pre-processing (Delayed)	N+11, N+13 (3.0)
9. Controller Alert (Resolution Notification)	N+5, N+6 (1.5)	22. Conflict Pair Removal	N+12.5 (1)
10. Terrain/Airspace/ Obstacle Avoidance	N+5, N+13 (9)	23. State Vector Deletion	N+13 (0.5)
11. Coarse Screen	N+5, N+6 (1.5)	24. Conflict Table Seam Deletion	N+13.5 (0.5)
12. Conflict Table Seam Addition	N+5, N+6 (1.5)	25. Data Link Message Construction	N+14 (1)
13. Detect	N+5, N+6 (1.5)	26. Uplink	N+15 (1)

TABLE 3-2

MAJOR DATA STRUCTURES FOR ATARS SECTOR PROCESSING

Surveillance Input Data (Antenna Sector)

XINIT List (ATARS Sector)

X, EX-Lists (ATARS Sector Threading)

Coarse Screen Pair List (Per Sector)

Resolution Encounter List (Per Sector)*

Normal Resolution Encounter List (Per Sector)*

Delayed Resolution Encounter List (Per Sector)*

Proximity Encounter List (Per Sector)*

Resolution Deletion Encounter List (Per Sector)*

Controller Alert List (Per Sector)

Controller Alert List Buffer (Per Sector)

Deletion List (Per Sector)

---

* See Table 7-12 for contents of these data structures

3.2 Sequencing of ATARS Processing Tasks

Figure 3-1 presents the highest level flow diagram, which displays the sequencing of all the major tasks for ATARS sector processing. The major delivery points for the input/output buffers are indicated on the diagram. The numbers in the boxes denote critical points in the task sequencing where several tasks must be completed before starting the next task. It is extremely important that the tasks be executed in the order shown in Figure 3-1 for each sector of data. Each task in the sector processing sequence has a defined "window" in which all computations for the particular sector of data must be completed (see Table 3-1). The individual tasks involve other routines which are necessary to complete the assignments for a given task.

The following discussion describes the operation of the ATARS sector processing at the highest level and represents the performance of all tasks on data from one ATARS sector. Through the executive control, this sector process is applied individually to the data from all ATARS sectors in the manner described in Section 3.1.

The first major input data processor is the Non-surveillance Data Processing Task which accepts non-surveillance data from DABS on a sector basis through the Non-surveillance Buffer. The messages are processed once per sector at the initiation of report processing. These messages apply only to DABS aircraft and do not contain CIR information. The output of the non-surveillance task is added to the aircraft state vectors and conflict tables accordingly.

The second major input data processor is the CIR Processing Task. CIR information is received through the CIR Buffer. The messages are processed once per sector at the initiation of report processing. The primary function of the CIR processor is to examine the contents of the CIR of aircraft with collision avoidance avionics equipage each time this data is downlinked and to update the information in the ATARS conflict tables accordingly. CIR processing notes the acceptance of resolution advisories and handoff messages uplinked by the local ATARS site and records the existence of resolution advisories and handoffs generated by other systems. For conflicts involving a controlled aircraft, the CIR Processing Task also updates the Controller Alert List to show resolution advisories which have actually been delivered by the various collision avoidance systems.

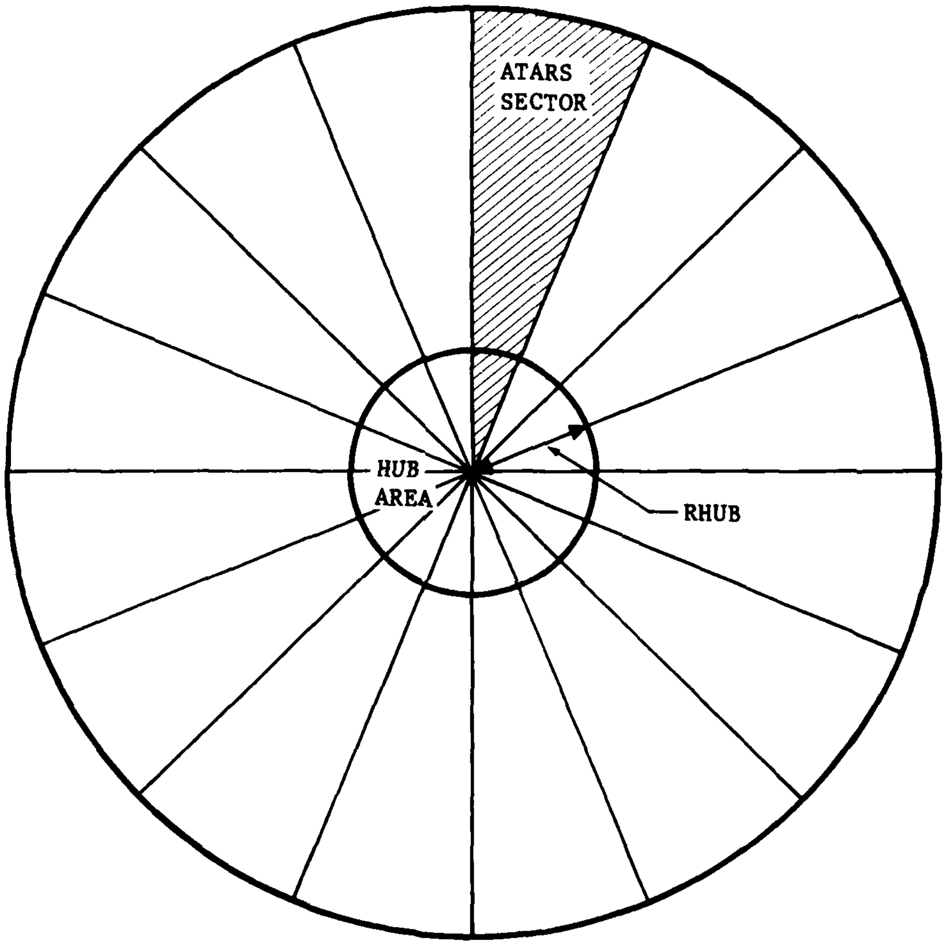
The third major input data processor is the Report Processing Task. The information for this task is received through the Surveillance Buffer and the reports are processed once per sector. A decision is made on whether the reports fall inside the ATARS surveillance area and, if so, DABS and ATCRBS tracks are initiated with an aircraft state vector and added to the antenna sector list.

A fourth task which processes input data is the Incoming Seam Pair Request Processing and Reply Task. The data for this task is received through the Remote Site Coordination Buffer. This buffer operates as a two-way exchange, providing input and accepting outputs from this task. The incoming seam pair request task processes messages received over ground lines from neighboring ATARS sites. These messages are requests for conflict tables involving specified pairs of aircraft. This task identifies the aircraft in the request and returns own-site's copy of the conflict tables, if any.

After report processing has initiated new tracks or associated reports with existing tracks, the Track Processing Task performs track updates through the smoothing and prediction algorithms. As new tracks are qualified for ATARS service, they are added to an aircraft initiation list in this task. These aircraft are then added to the ATARS data base in the New Aircraft Processing Task. The new aircraft are linked into the data base to be included with aircraft in the ATARS sector for which they are identified. The Track Processing Task performs the final elimination of tracks which are not to be serviced by ATARS.

Each aircraft in the sector now has its position updated to a common sector time in the Aircraft Update Processing Task. This is necessary because track reports are received from both the local sensor and other remote sensors and the data received on all aircraft will have been measured at different times. To eliminate the errors that might be introduced into the ATARS calculations by dealing with data measured at different times, the positions of all aircraft in the sector will be time-adjusted to a common sector time.

The area near the radar site providing the surveillance data for ATARS must be given special consideration in this task during sector processing. This area is designated the hub area and is defined by a circle of radius RHUB (approx. 10 nmi) from the radar site (Figure 3-2). The position of all aircraft in the area must be updated every quarter scan (approx. 1.2 sec). This is necessary in sector processing because data is processed in sector groups and a small position change in the area may move an



RHUB - RADIUS OF HUB PROCESSING AREA

FIGURE 3-2
DIAGRAM OF HUB PROCESSING AREA AS CONTAINED IN THE ATARS SERVICE AREA

aircraft one or more sectors from its last sector location. Thus, an updated sector identification and position is maintained for aircraft in the immediate vicinity of the radar site, or of the ATARS area, four times per antenna scan.

Using the updated data base, a sector of aircraft is processed in a parallel mode by the following three tasks: Coarse Screen Processing Task, Conflict Table Seam Addition Task, and Terrain/Airspace/Obstacle Avoidance Task.

The Coarse Screen Processing Task searches the data base for aircraft that are potentially in conflict with this sector list of aircraft. This search is implemented through the use of two independent doubly linked lists which are ordered on the X-coordinates of the aircraft. Each aircraft is contained on one list or the other. The two lists are maintained in order to make the search for potential conflict pairs more efficient. All aircraft which would require large search limits because of high speeds or other factors are placed on one list called the EX-list and all other aircraft are placed on the other called the X-list. In coarse screening one individual aircraft is compared with its neighbors on its own list (and possibly with some aircraft on the other list, as well) to find a pair of potentially conflicting aircraft. A pattern of searches has been devised that avoids duplicate detection of potentially conflicting pairs. The pairs of aircraft which are identified are entered on the Coarse Screen Pair List for this sector.

The Conflict Table Seam Addition Task examines all conflict tables to determine whether they contain any aircraft in an ATARS seam in this sector list. Whether an aircraft is in a seam is determined by the Aircraft Update Processing Task. If this aircraft is in a seam, the seam flag in the table is set.

The Terrain/Airspace/Obstacle Avoidance Task has the capability to provide an alert for the violation of restricted airspace, close proximity to the terrain, and close proximity to an obstacle. This task operates on the sector list of aircraft and only affords service for those aircraft in the ATARS service area. The logic to determine the need for an alert is provided in this task, while the actual construction of the message is performed by the Data Link Message Construction Task later in the sector processing sequence.

Processed in parallel with the above three tasks is the Controller Alert (Resolution Notification) Task. This task processes all pairs on the Controller Alert List for the

sector. It deletes pairs not updated for two scans. The controller alert logic initially sends conflict resolution data for pairs in conflict and later sends resolution notices for aircraft which have received resolution advisories.

The Coarse Screen Pair List for the sector is used by the Detect Task. Detection determines if a conflict situation exists for each pair on the list. The output of the Detect Task is a group of eight flags which indicate if a controller alert, proximity advisory, threat advisory or resolution advisory are required.

This output for each pair identified with the sector number is placed in one of the following lists: Proximity Encounter List, Resolution Deletion Encounter List, or Resolution Encounter List.

Pairs that require only a traffic advisory (no resolution processing) are placed on the Proximity Encounter List; however, if the pair was previously in resolution status, it is placed instead on the Resolution Deletion Encounter List. Pairs on both of these lists are input to the Data Link Pre-processing Task to determine the correct traffic advisory. The Proximity Encounter List is available to be used by the Data Link Message Pre-processing (Proximity) Task as soon as detection places pairs on the list. Message pre-processing is executed in three different places in the sequencing of tasks, and all its various functions are discussed at this time. The Data Link Message Pre-processing Task creates, updates, and deletes entries on a list maintained for each subject aircraft. Entries on the list contain data for other aircraft which are in conflict with the subject aircraft.

Pairs which are currently in resolution status are processed by the Master Resolution Task, either Normal or Delayed. All such pairs are then input to the Data Link Pre-processing Task to determine the corresponding traffic advisory. Other pairs which would qualify for resolution status, except that the local ATARS does not have resolution authority under the multi-site protocol, are also placed on the Proximity Encounter List as above.

The use of the Resolution Deletion Encounter List for the sector is delayed after the completion of the Detect Task until the Conflict Pair Removal Task is initiated. This task is discussed later in the sequencing.

The Resolution Encounter List for the sector along with the results of the Conflict Table Seam Addition Task are used as

input for the Seam Pair Task. This task determines own-site resolution responsibility for each pair on the Resolution Encounter List. If own-site is responsible and either aircraft is in an ATARS seam, the task places the pair on the Delayed Resolution Encounter List. The Seam Pair Task places the pair on the Normal Resolution Encounter List if neither aircraft is in a seam. Pairs are also placed on the Controller Alert List Buffer at this time. If own-site does not have resolution responsiblity but CMDFLG is set, the pair is placed on the Proximity Encounter List and is available for immediate processing by the Data Link Message Pre-processing Task.

The Controller Alert List Buffer for the sector is used by the Controller Alert (Conflict Resolution Data) Task and is available for processing as soon as the entries are on the list. The task processes pairs on the Controller Alert List Buffer and initializes or updates entries on the Controller Alert List. When each entry reaches an acceptable confidence level, a Controller Alert Message is generated containing conflict resolution data.

The Normal and Delayed Resolution Encounter Lists for the sector are processed in parallel by the Master Resolution (Normal) Task and the Request and Process Remote Conflict Tables Task respectively. The Master Resolution (Normal) Task provides the framework for the initial selection of resolution advisories, the monitoring of the conflict to adjust advisories to more restrictive or less restrictive maneuvers as the situation warrants, the staging of advisories in an uncontrolled/controlled encounter, and the recomputing of advisories when the initial maneuvers are ineffective. This is accomplished through the use of the Normal Resolution Encounter List, pair records, and conflict tables. The logic for providing the selection of the best resolution maneuver for a pair of aircraft given the current set of constraints is the Resolution Evaluation Routine which is called by the Master Resolution Task. This logic performs a fast-time simulation of all possible sets of maneuvers and selects the one that will provide the greatest safety after considering many factors. Some of these factors are the separation at closest approach, the turn status of each aircraft, the likelihood of a domino conflict, and the vertical and horizontal maneuver performance of the aircraft. The logic evaluates multi-aircraft situations by considering the current maneuver constraints when determining resolution advisories for a new conflict.

The Request and Process Remote Conflict Tables Task requests a copy of conflict tables from all neighboring sites involved with

a seam pair. The reply is processed to add, update, or delete from the own-site's confict tables any pair record which is, or was previously, controlled by the neighboring site. This information must be obtained and processed before the Master Resolution (Delayed) Task is begun for the sector.

After the Master Resolution (Normal) Task updates conflict tables, the Data Link Message Pre-processing Task is initiated for the pair. The functions of the pre-processor are defined above after the discussion of the Detect Task.

Before the completion of the Master Resolution (Normal) Task, the Master Resolution (Delayed) Task is initiated for the sector's aircraft pairs found on the Delayed Resolution Encounter list. The Delayed Master Resolution Task provides the same service to the aircraft pairs as the Normal Master Resolution Task. The updated conflict tables are afforded processing in the Data Link Message Pre-processing Tasks the same as they were after normal master resolution was completed.

At the completion of normal and delayed master resolution, the Conflict Pair Removal Task is initiated. The Conflict Pair Removal Task has the general purpose of ensuring that conflict pair data in the conflict tables is closed out in the proper manner when it is no longer needed. This task initiates the uplink of null resolution advisories for conflicts which were resolved by the local site, ensures that handoff messages continue to be uplinked until they are received, and deletes pair records whenever it is made possible by an aircraft flying out of the local site's coverage area. Primary input to the task is the linked list of conflict tables.

After the completion of the Conflict Pair Removal Task, the State Vector Deletion Task is initiated for the sector. This task deletes the State Vector and ends tracking of an aircraft which leaves the ATARS/Domino Mask. If the aircraft is involved in a conflict, an entry is made on the remote list of aircraft. If ATARS has unfinished business with the aircraft, such as a message indicating handoff status, the above actions are inhibited.

At the completion of the State Vector Deletion Task, the Conflict Table Seam Delete Task is initiated. This task examines all conflict tables to see if any tables which had the SEAM flag set no longer contain any aircraft in a seam. If so, SEAM is reset.

The last task to be executed in the sector sequencing is the Data Link Message Construction Task. This task processes the sector's list of aircraft and generates all messages required for each aircraft. The task reads the PWI List containing all conflict data and generates conflict messages for aircraft in conflict. If the aircraft is a new entry in the ATARS data base, it generates a message containing tracking data. If the aircraft is in restricted airspace, or in proximity to the ground or other obstacles, it generates a message containing warning data.

3.3 External Interfaces

The ATARS external interfaces go through the DABS sensor. Even though ATARS sends messages to ATC facilities, aircraft and other sites, and receives messages from these sources, all communications are handled through the local DABS sensor. The exact physical character of the interfaces and the buffer formats between DABS and ATARS are found in Reference 1. The contents of the report formats are discussed in this section for clarification.

A diagram of the ATARS-SENSOR interface is illustrated in Figure 3-3. Note that some of the information flows in one direction only (DABS-to-ATARS, ATARS-to-DABS) and the remainder flows in a two-way buffer. The ATARS buffers noted in the diagram are serviced by the appropriate task.

The input-only information from the DABS sensor to ATARS consists of reports in the following three buffers:

1. CIR Buffer

2. Surveillance Buffer

3. Non-surveillance Buffer

These buffers are written by the DABS sensor and read by ATARS. They are two-segment buffers with one segment being written at the same time that the other segment is read. Overwriting a segment which is being read must be prevented by a lockout flag or by careful program timing.

Input data for all three buffers is transmitted in blocks consisting of all the surveillance, CIR or message reports available to the local sensor (local or remote reports) during one 11 1/4 degree sector of local antenna rotation. A single

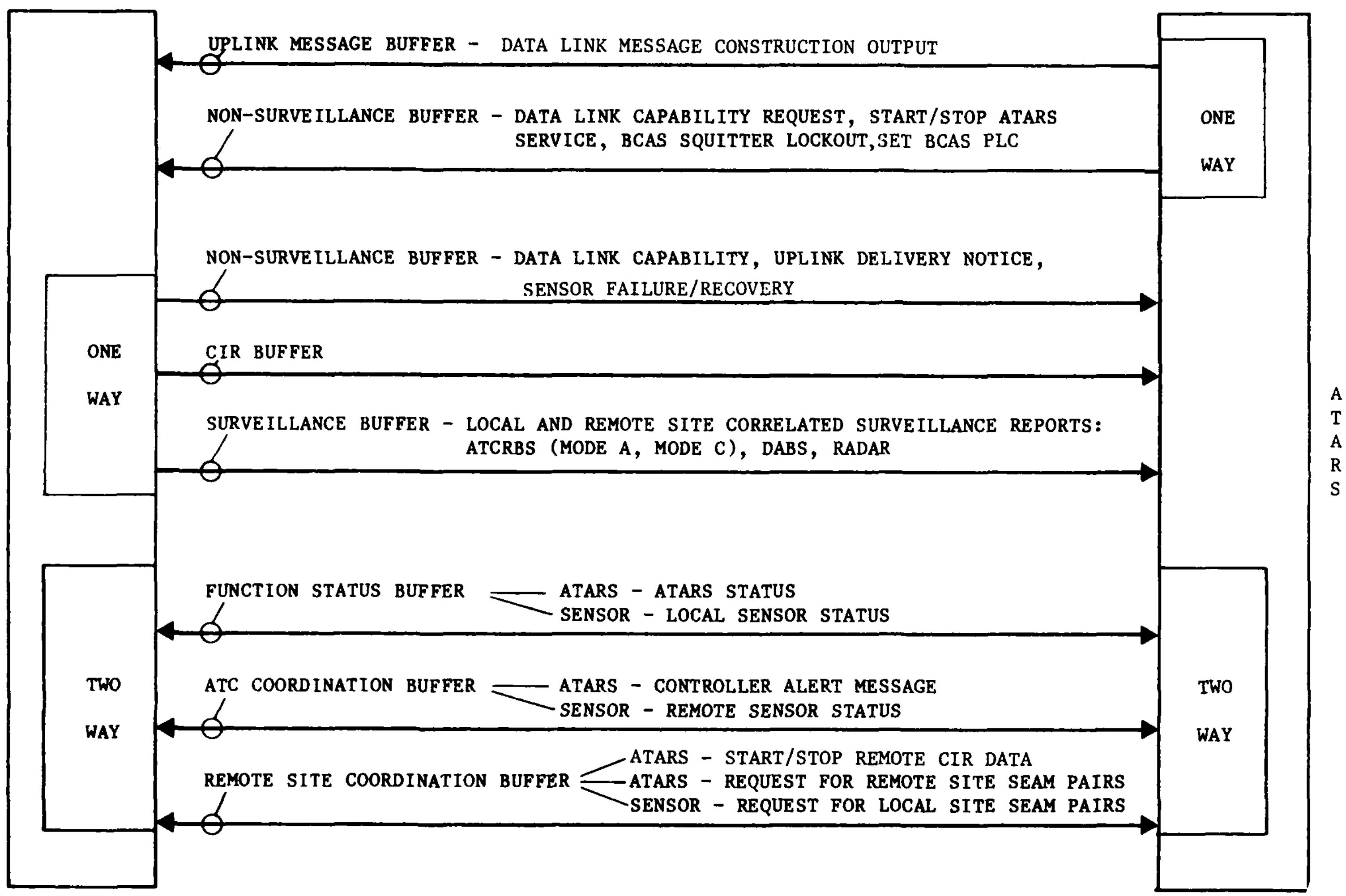


FIGURE 3-3
ATARS-SENSOR INTERFACE DIAGRAM

completion interrupt is then given to the ATARS processor. Just before the interrupt, a special header word is filled in each Surveillance Buffer with the current local sector identification number and sector time (see Figure 3-4).

The Surveillance Buffer contains reports utilized by the ATARS Track Processing Task. The local or remote reports are disseminated to ATARS using the formats given in Table 3-3 for DABS and Table 3-4 for ATCRBS reports. These reports are outputs of the DABS sensor tracker correlator; uncorrelated reports do not occur. These reports are accepted in their entirety, as ATARS is a non-correlating user of DABS.

The CIR Buffer contains all the CIR information which has accumulated during the time represented by the rotation of the sensor antenna through one sector. The CIR Buffer contents are read by the CIR Processing Task and the information is passed along to the appropriate ATARS tasks.

The Non-surveillance Buffer contains all messages which have accumulated during the time represented by the rotation of the sensor antenna through one sector. The formats of these messages are indicated in Section 5.

The output-only information from ATARS to the DABS sensor consists of reports in the following two buffers:

1. Uplink Message Buffer

2. Non-surveillance Buffer

The ATARS messages generated for the aircraft through the Data Link Message Construction Task are delivered to the Uplink Message Buffer. All the data link capability requests, start/stop ATARS service, and BCAS squitter lockout are delivered to the Non-surveillance Buffer.

The two-way buffers provide information from ATARS-to-DABS and from DABS-to-ATARS. These two-way reports are transferred in the following buffers:

1. Function Status Buffer

2. ATC Coordination Buffer

3. Remote Site Coordination Buffer

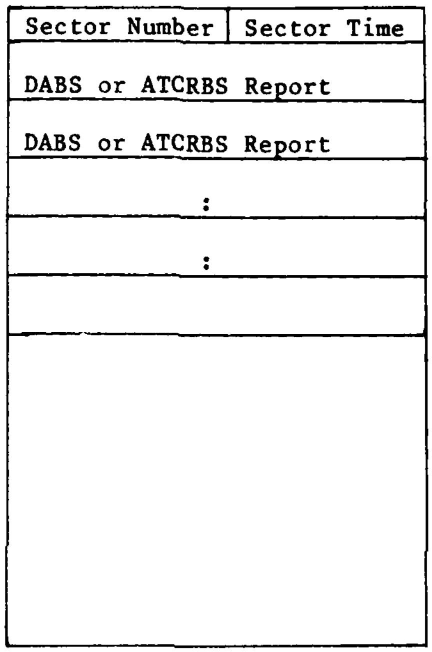


FIGURE 3-4
SURVEILLANCE BUFFER DATA STRUCTURE

TABLE 3-3

DABS REPORT FORMAT*

Fields	Length (Bits)
Test	1
Format Type	2
Radar Substitution	1
Cone of silence flag set in local sensor	1
Mode C not decoded	1
Altimeter correction	8
Sensor Priority Status	1
Primary Coordination in Progress	1
Radar Reinforced	1
Code 7700	1
Code 7600	1
Radar Only	1
Alert	1
Control status	1
Reply Type	3
Null Report	1
Track Start	1
Track Drop	1
Range**, LSB = 1 Ru (1/16 us)	16
Azimuth, LSB = 1 Au (0.022°)	14
Mode C altitude, LSB - 100 feet	12
DABS ID	24
Sensor ID	4
Site ID Bits	4
Measurement time, LSB - 1/16 second	8
Primary/Secondary status	1
Diffraction Zone flag	1

* The exact form of this data is provided in Reference 1.

** This is a two-way range expressed in units of time.

TABLE 3-4

ATCRBS REPORT FORMAT*

Fields	Length (Bits)
Test	1
Format Type	2
Radar Substitution	1
Cone of silence flag set in local sensor	1
Mode 3/A present	1
Mode C present	1
Altimeter correction	8
Mode C not decoded	1
SPI (IDENT)	1
Radar Reinforced	1
Code 7700	1
Code 7600	1
Radar Only	1
False target flag	1
Null Report	1
Track Start	1
Track Drop	1
Range**, LSB = 1 Ru (1/16 us)	16
Azimuth, LSB = 1 Au (0.022°)	14
Mode C altitude, LSB = 100 feet	12
Mode 3/A	12
ATCRBS Surveillance File No.	12
ATCRBS code in transition	1
Sensor ID	4
Measurement time, LSB = 1/16 second	8
Control Status	1
Diffraction Zone Flag	1

* The exact form of this data is provided in Reference 1.

** This is a two-way range expressed in units of time.

The Function Status Buffer delivers ATARS status to DABS and local sensor status to ATARS. The ATC Coordination Buffer delivers Controller Alert Messages from ATARS to DABS for the ATC facilities and remote sensor status from DABS to ATARS. The Remote Site Coordination Buffer delivers ATARS requests for remote site seam pairs to DABS and requests for local site seam pairs to ATARS from DABS. The Remote Site Buffer also delivers the start/stop request for remote CIR data.

3.4 Aircraft State Vector

The aircraft state vector used by the ATARS processor is presented in Table 3-5. The state vector contains all the known information for a particular aircraft that is being tracked by ATARS. The data is listed in the table under four categories:

1. Tracker Data

2. Pointer Parameters

3. Flag Parameters

4. Numerical Parameters

The nomenclature for each data parameter may be used in this document with the number 1 or 2 added as a suffix (e.g., XDE, XDE1, XDE2). When the parameter appears without the numerical suffix, a single aircraft is being addressed in the discussion. In such a single aircraft situation, parameters may also appear with a 1 as a suffix. When two aircraft are being compared, it is necessary to identify the parameters from each aircraft's state vector. To do this, a 1 is added to the subject aircraft's state vector parameters and a 2 is added to the object aircraft's state vector parameters.

The individual aircraft state vectors are placed in a file called the Central Track Store (CTS). The CTS is a convenient location to access all tracks for the ATARS processor. Detailed information for the CTS usage is found in Section 4.3.

3.5 En Route Operation

ATARS is required to provide service in en route areas as well as terminal areas. Certain characteristics of the en route environment require that the ATARS system operating in the en route area differ slightly from that in the terminal area. The body of this document addresses the ATARS system in a terminal area. This section describes the ways in which ATARS in the en route area differs.

TABLE 3-5

STATE VECTOR

TRACKER DATA

Nomenclature	Meaning
X	X position of aircraft
Y	Y position of aircraft
Z	Z position of aircraft
XP	External one scan predicted X position
YP	External one scan predicted Y position
ZP	External one scan predicted Z position
XPI	Internal one scan predicted X position
YPI	Internal one scan predicted Y position
XD	X velocity of aircraft
YD	Y velocity of aircraft
ZD	Z velocity of aircraft
XDE	External X velocity estimate
YDE	External Y velocity estimate
ZDE	External Z velocity estimate
XDI	Internal X velocity estimate
YDI	Internal Y velocity estimate
VSQ	Square of the horizontal speed estimate, $XDI^2 + YDI^2$
FIRMI	Internal firmness level
FIRME	External firmness level
FIRMZ	Altitude firmness level
RHOP	Predicted range of track at next data correlation time
AZP	Predicted azimuth of track at next data correlation time
TM	Time of last reported Range/Azimuth data
TMZ	Time of last reported Altitude data
TMR	Time of current remote Range/Azimuth, Altitude data
TMP	Expected time of next local data
TD	Approximate time at which ATARS message was received by aircraft

TABLE 3-5

STATE VECTOR
(Continued)

POINTERS

Nomenclature	Meaning
ACMES	Pointer to last set of ATARS messages successfully delivered to aircraft
ATCREF	Pointer to entry in CREFX for ATCRBS aircraft
CTE	Pointer to conflict table entry for this aircraft
CTPTR	Pointer to head of the conflict table which contains table entry for this aircraft
CUROWN	Pointer to current Own Message data
LSTOWN	Pointer to last successfully delivered Own Message data
NEXTA	Pointer to the following aircraft in the ATARS sector list thread
NEXTS	Pointer to the next aircraft in the antenna sector list thread
NEXTX	Pointer to the next aircraft in the X-list or EX-list thread
PREVX	Pointer to the previous aircraft in the X-list or EX-list thread
PWPTR	Pointer to list of PWI's for aircraft
STKPTR	Pointer to the stack of three positions, velocities and times used for turn rate computation
UPMES	Pointer to last set of ATARS messages released to uplink

TABLE 3-5

STATE VECTOR
(Continued)

FLAGS

Nomenclature	Meaning
ATSS	Flag indicating that aircraft is ready for ATARS service (i.e., it is in the XINIT list)
BCLO	Flag indicating BCAS lockout condition
CENTR	Flag that indicates this aircraft is in the center area of the ATARS service area
DELFG	Flag to identify the state vector of an aircraft to be deleted
DLOUT	Flag that indicates that local sensor lost data link contact with aircraft on most recent scan
DRATS	Flag indicating that this aircraft was dropped by the ATARS tracker
DRSUR	Flag indicating that this aircraft was dropped by the sensor
EXFLG	Flag that indicates whether aircraft is linked on X-list or EX-list of pointers
HUBFLG	Flag to indicate that aircraft is in a zone close to the antenna and needs special position processing
INXFL	Flag for new aircraft on the XINIT list
LOFL	Flag indicating that this aircraft has local data

TABLE 3-5

STATE VECTOR
(Continued)

FLAGS (Concluded)

Nomenclature	Meaning
OBAFLG	Flag indicating that an Obstacle Avoidance Message is required this scan
OSCFL	Flag indicating that RETCIR will be reset after one scan
RESFLG	Flag to indicate restricted airspace alert
RMFL	Flag indicating that this aircraft has remote data
SMPR	Flag indicating that this aircraft's data has been smoothed and predicted this scan
SPIDFG	Flag set for all signpost state vectors for identification in coarse screen
SPRO	Antenna sector processing flag
TCAFLG	Flag to indicate TCA alert
TRAFLG	Flag indicating that a Terrain Avoidance Message is required this scan
XUPFL	Flag to prevent multiple updates when editing X-list/EX-list of pointers

TABLE 3-5

STATE VECTOR
(Continued)

NUMERICAL DATA

Nomenclature	Meaning
ACAT	Aircraft area type
ATSEQ	ATARS equipped, BCAS and ATARS equipped, or neither (unequipped)
CODE	DABS Code or latest 3/A Code
CUNC	Status variable indicating whether aircraft is controlled or uncontrolled
FAZ	Final Approach Zone indicator
FILE	ATCRBS surveillance file number; not used for DABS
GEOG	The geographical zone of the aircraft
HMS	Horizontal maneuver status, used in the X-Y tracker
PSTAT	Indicator that tells local site's primary/secondary status with respect to this aircraft
RASFLG	Indicator that a Restricted Airspace Avoidance or TCA Alert Message is required this scan.
REMCIR	Identity of remote site from which CIR data will be (if negative) or is being (if positive) requested
RETCIR	Identity of remote site to whom CIR data is being returned
SVSID	Sector identity of the aircraft used to group a set of aircraft in a sector
SLREPS	Slant range from sensor providing the most recent surveillance report
TURN	Horizontal maneuver status, used in Detect and Master Resolution Tasks

TABLE 3-5

STATE VECTOR
(Concluded)

NUMERICAL DATA (Concluded)

Nomenclature	Meaning
TYPE	Status variable indicating whether the aircraft is DABS, INDABS or ATCRBS
ZPRT	Call letters of airport associated with Final Approach Zone (FAZ)
----	Data blocks for storing DABS or ATCRBS reports described in Table 3-3 or Table 3-4

3.5.1 ATARS Operation With Back-To-Back DABS Antenna

DABS sensors are to be installed at sites where current ATC en route radars are in operation and are to be operated in conjunction with the en route primary radars. The primary radars operate with a scan time of 10 to 12 seconds. If the DABS sensor were required to operate with a data rate corresponding to this scan time, the ATARS service that could be provided would be unacceptable. To improve the ATARS service, the DABS sensor has been designed to operate with a back-to-back antenna (an antenna with two faces directed 180 degrees apart) rotating with a scan time of 10 to 12 seconds. The effective data update interval is then 5 to 6 seconds.

The operation of the DABS sensor with the back-to-back antenna is described in Reference 1. The modifications to the normal ATARS algorithms that are required for operation with the back-to-back antenna are described in this section. The remainder of this document describes algorithms for operation with a normal DABS sensor (scan time on the order of 4.7 seconds).

A sector will still be defined as a sweep of 11 1/4 degrees. When an input completion interrupt is received, data for two sectors will be passed through the Surveillance Buffer. This data will be the data collected from the front face and the back face of the antenna while the antenna rotated through 11 1/4 degrees. The two sectors represented are 180 degrees apart. The data from both sectors will be serviced by the report processing algorithms. Sector header data will be provided for each sector of data.

One change to be made when ATARS is operated with a back-to-back antenna is the time at which second-pass processing is performed in the Track Processing Task. Second-pass processing is normally done in sector n-20. With the back-to-back antenna, it should be done in sector n-12. This change is made so that the processing of remote data (which now occurs four times per scan instead of the normal two) will occur at times equally distributed throughout the scan, and so that all operations in a given sector on data from the front-face of the antenna (including resetting of the smooth/predict and report process flags) will be complete before any operations with data from the back-face will be started for that sector. The tasks performed during second-pass processing will not be changed in any way; only the time of performing second pass processing is changed.

The sector processing executive logic must be modified so that the sector list of aircraft from each face of the antenna can be processed as a separate stream. When the antenna enters a new sector, the ID's of both the front-face and the back-face sectors will be added to the sector request stack. The sectors will then be processed as separate streams through the ATARS logic. The time allowed to complete each processing task must be adjusted so that advisories detected on the front-face of the antenna will be available for uplink on the next sweep of the back-face of the antenna. The primary radar associated with an en route DABS sensor will have only one antenna face. This face will be matched with the front-face of the DABS sensor antenna. Hence, radar-only tracks will be processed once per scan. It is necessary to have antenna position reports supplied to ATARS once per sector for only the front-face.

In prediction, with the back-to-back antenna, positions should be predicted to the time of next expected data. This will be a prediction over a half scan rather than a full scan. ATARS will be able to deliver resolution advisories on the uplink on either the front-face beam or the back-face beam.

3.5.2 Modification of ATARS Detection Parameters

Another characteristic of the en route area, in addition to the slower scan rate, is the operation with larger aircraft-to-sensor ranges and a resultant reduction in position and velocity tracking accuracy. To provide acceptable operation at larger ranges, ATARS must use increased conflict detection parameters. Currently, ATARS tests the aircraft in a pair before selecting a set of detection parameters for that pair. If either aircraft is outside a specified area, the detection parameters for that pair are increased. Additional parameters that are specifically related to the en route environment will be supplied in the future.

4. SURVEILLANCE DATA AND TRACK PROCESSING

4.1. General Requirements

ATARS surveillance processing may be divided into three main subfunctions: input processing, track processing, and smoothing/ prediction. The general division of responsibility is that input processing accepts target reports from DABS sensor processor and screens and prepares them for tracking. Track processing maintains a file of system tracks and selects particular target reports for track update. Smoothing and prediction utilizes the selected reports for production of fresh position and velocity updates.

ATARS surveillance processing is required to track those DABS and ATCRBS Mode C equipped aircraft which are being tracked by the local sensor in the ATARS service area. ATCRBS aircraft without Mode C or outside the area are not tracked.

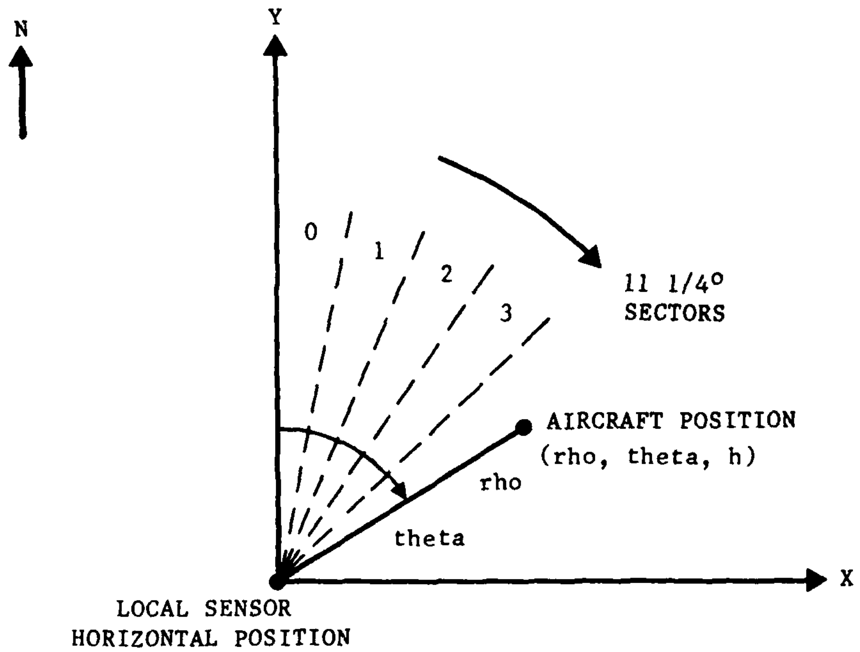
4.2 Coordinate Systems

Target reports are received in the rho, theta, h (slant range, azimuth, altitude) system of the DABS sensor. ATARS maintains and uses track estimates in a modified Cartesian X, Y, Z system. The local sensor lies at the center of the X, Y grid with X east and Y north (see Figure 4-1).

Mapping between these two systems is based on a flat earth assumption. Under this assumption X, Y are considered as the ground plane projection coordinates of an aircraft, while Z is identical to the altitude. However, because of the actual curvature of the earth, the X, Y, Z which are so computed do not exactly correspond to the aicraft position in a physical Cartesian space. Nevertheless, the X, Y, Z descriptions produced by this formal mapping will be utilized throughout the ATARS processing. The equations of the mapping are shown in the figure.

Geographical corrections take place in rho, theta. Reports selected for track update are coordinate converted to the X, Y, Z system before using them to smooth the track estimate. The inverse
mapping is used to determine a predicted rho, theta for the next correction and for antenna sector update.

In converting remote reports to local X, Y, Z coordinates, any method of calculation may be used which accurately accounts for



TARGET MEASUREMENTS: RANGE rho
AZIMUTH theta
ALTITUDE h

SENSOR ALTITUDE: h_s

SLANT RANGE CORRECTION: $rho' = \sqrt{rho^2 - (h - h_s)^2}$

TRACK COORDINATES: X = rho' sin(theta)
Y = rho' cos(theta)
Z = h

FIGURE 4-1
ATARS TRACK SECTORIZATION AND COORDINATES

the real spatial geometry. In order to be useful in tracking, the truncation errors in conversion must be kept comparable to the random data error (i.e., approx. = 100 feet or less). The method should be reasonably efficient, but since remote report conversion will only be occasionally required, some complexity can be tolerated.

4.3 Major Files

The ATARS track file is a separate creation of the ATARS function and is not identical, either physically or in content, to the DABS sensor track file. This file (the Central Track Store (CTS)) consists of a block of track slots, of sufficient size to accommodate the maximum track load. Each slot may either be empty or it may contain track information (aircraft state vector) about a particular aircraft. In addition, a number of slots of known fixed X coordinate distance called signposts provide quick points of entry into the appropriate X-list as described in Section 6.4. Signposts are bookkeeping aids and are not altered by the tracking programs.

A CTS file is used to transmit information for a particular aircraft throughout the various tasks in the ATARS processing cycle. The central track store contains three basic categories of information: position, velocity, time estimates; status and ID indicators; and control flags.

The tracks in CTS must be rapidly accessible in two ways for Report Processing and Track Processing Tasks: on a geographical antenna sector basis and by aircraft ID. 32 fixed azimuth sectors are defined with respect to the local sensor, beginning clockwise from north (see Figure 4-1). Each antenna sector is 11 1/4 degrees wide. Tracks are organized (e.g., by threading) so that the ATARS tracker can efficiently index and process tracks lying in a particular antenna sector. Since the aircraft move, their antenna sector assignements will change. These changes are monitored, and an updated antenna sector organization is maintained.

Rapid access of individual tracks through their ATCRBS surveillance file number or DABS ID is accomplished by establishing a cross-reference file for each of these aircraft classes. These files which are denoted CREFA and CREFD, respectively, relate the input code (which may be compressed by hashing) to the corresponding track slot number in CTS. When tracks are dropped or new tracks are started, the cross-reference files are correspondingly updated. These file relations are indicated in Figure 4-2.

Since the ratio of ATCRBS to DABS track loads is an environmental variable, it is desirable that CTS not be partitioned in any fixed way between these two track classes. Procedures for organizing and accessing CTS should remain efficient regardless of this load ratio.

4.4 Report Processing

The ATARS surveillance processing initiates and maintains ATARS tracks on all DABS and ATCRBS Mode C beacon equipped aircraft in the ATARS surveillance area which are being tracked by the DABS sensor. This objective is accomplished by two major tasks: Report Processing Task, discussed in this section, and Track Processing Task, discussed in Section 4.5.

Report processing operates on interrupt after all target reports for a new antenna sector have arrived in the surveillance input buffer. The surveillance inputs consist of target reports from the DABS sensor.

Input data are:

1. a sector header antenna azimuth word,

2. target reports from surveillance buffer.

The services performed are to:

1. update current antenna position and rate estimates,

2. screen local reports and reject all reports falling outside the ATARS surveillance area.

3. Correlate local and remote reports with tracks through DABS ID or ATCRBS file number cross-references. Store reports with the state vectors in CTS.

4. Start new DABS or ATCRBS tracks.

5. Flag tracks for drop (if indicated by sensor).

A general flow chart for the Report Processing Task is shown in Figure 4-3.

Notes on the logic:

1. The antenna position/rate update routine is outlined in Section 4.7.

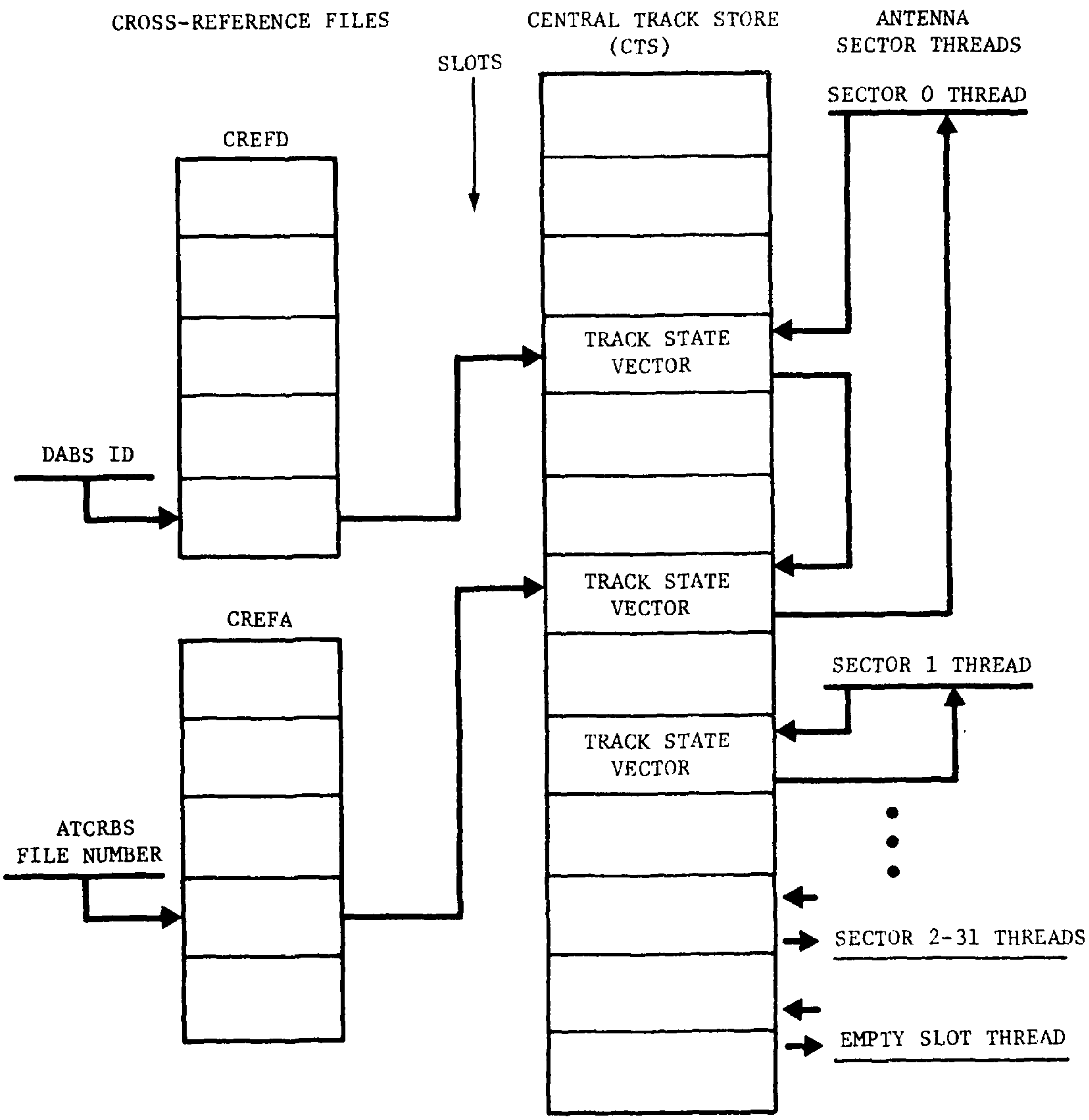


FIGURE 4-2
TRACK FILE STRUCTURE AND ACCESS

2. The ATARS service area is subtended by a larger area, defined by a rho, theta map. This map is defined as a convex figure encompassing the ATARS domino surveillance area as shown in Figure 4-4. Since the surveillance area is a convex figure, it suffices to define a map with a minimum and maximum rho for each theta (or theta interval). Two maps are required, one for reports above an altitude HZONE and one below this altitude (see Section 6.3). In order to pass the screen, a local report with altitude data must lie within the area appropriate for that altitude. If no altitude has been measured, then it must lie within at least one of the two map areas. (Remote reports cannot be mapped out efficiently here because their rho, theta are not local coordinates.)

3. When a local report passes area screening, and a remote report is not a null report, the DABS ID or ATCRBS file number is used to find the associated track in CTS (if any). The cross-reference files CREFD, CREFA provide the required links. If the track's drop flag (DRSUR) is set, it cannot accept further data and the report is ignored. Further, a local report must pass a rho, theta reasonability check of measured vs. predicted coordinates in order to merit further consideration. The report is then stored in the CTS report storage area.

4. When a local report is a null report, the NULLFG is set to indicate to the Track Processing Task that this particular track is to be treated as a "miss" rather than a "hit". If the Diffraction Zone Bit (DZB) is set in the report, the track is also processed as a "miss".

5. When a remote report is stored, the remote measurement time (TMR) is computed as the current clock time (TCLOCK) minus the report storage delay time (TDELA - as supplied with the report) and also stored. The remote flag is set.

When a local report is stored, the local data flag is set. Measurement time computation is done elsewhere (Track Update Routine).

6. For local reports associated with a track, the track drop bit is examined. If set, the track drop flag (DRSUR) is set.

Track drops can be initiated here, with a report drop bit indication, or later in Track Update Routine (Section 4.5.1)

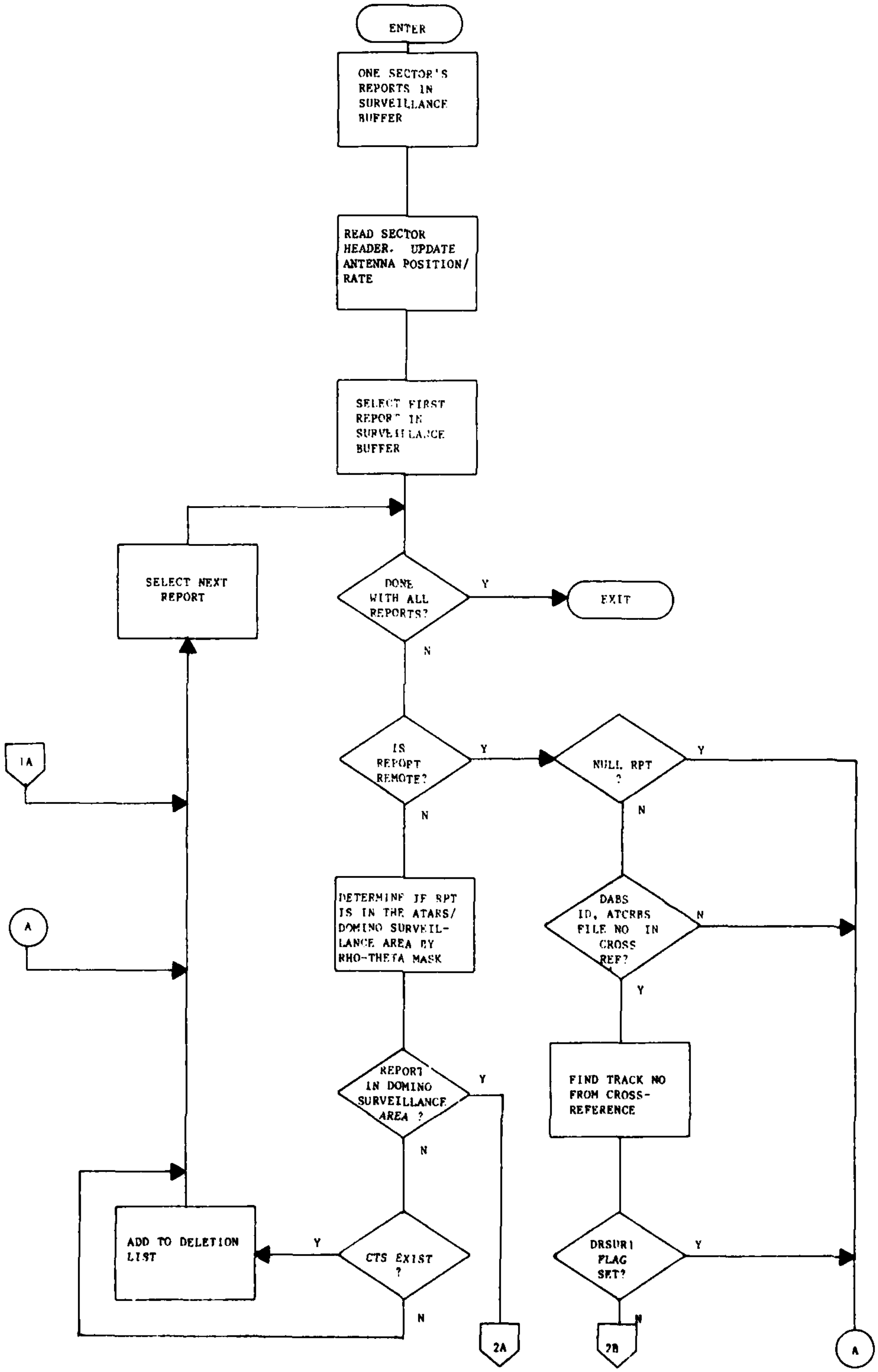


FIGURE 4-3
REPORT PROCESSING TASK (Page 1 of 2)

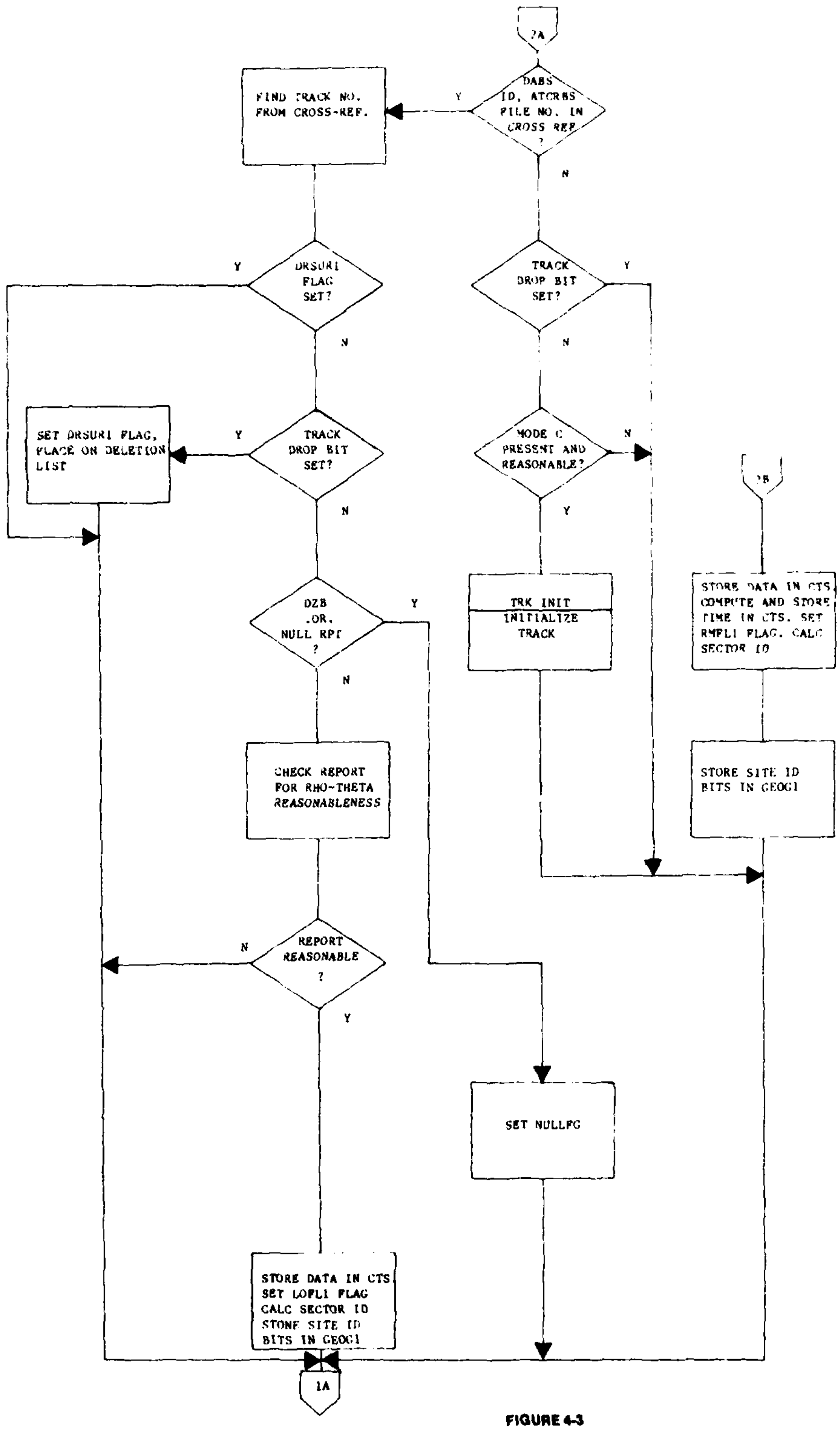
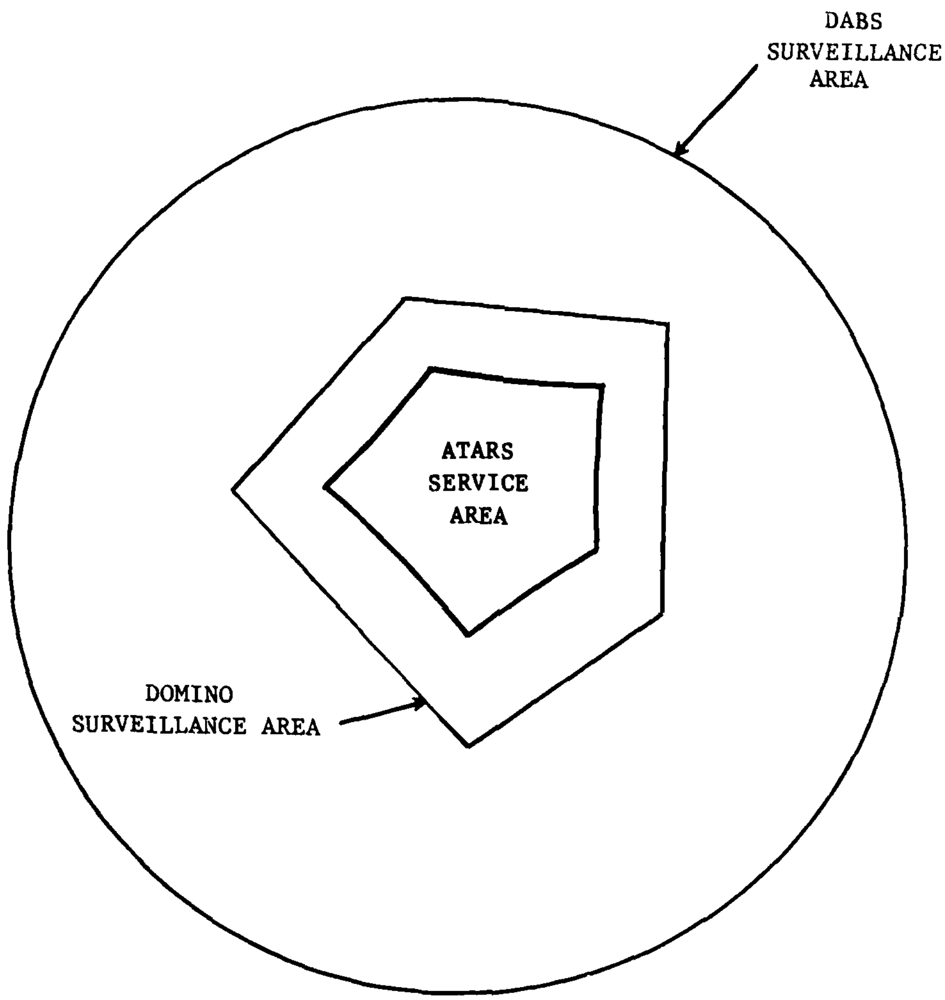


FIGURE 4-3
REPORT PROCESSING TASK (PAGE 2 OF 2)



DOMINO AREA - DOMINO AREA PROVIDES COVERAGE AT LEAST AN ADDITIONAL 15 N.M. BEYOND THE ATARS SERVICE AREA

FIGURE 4-4
ATARS AND DOMINO SERVICE AREAS

when data has been missing too long or the track is out of the ATARS service area. The State Vector Deletion Task performs the final drop action for tracks which have been in ATARS coverage.

7. Track starts are solely a report processing function. They occur when a local report is examined which does not have an existing associated track. The report is tested further to determine that:

a. The drop bit is not set.
b. Altitude data (Mode C) is available.
c. The indicated altitude is reasonable.

If these conditions are satisfactory, the Track Initialization Routine (Section 4.4.1) is utilized to begin a new track; otherwise, the report is ignored.

The Track Initialization Routine is shown in Figure 4-5. Track initiation occurs only through local beacon reports and is started with a single beacon report.

The following services are performed:

1. Find an empty track slot in CTS. Empties are threaded together into their own list using the sector thread mechanism. This slot will hold the new track state vector.

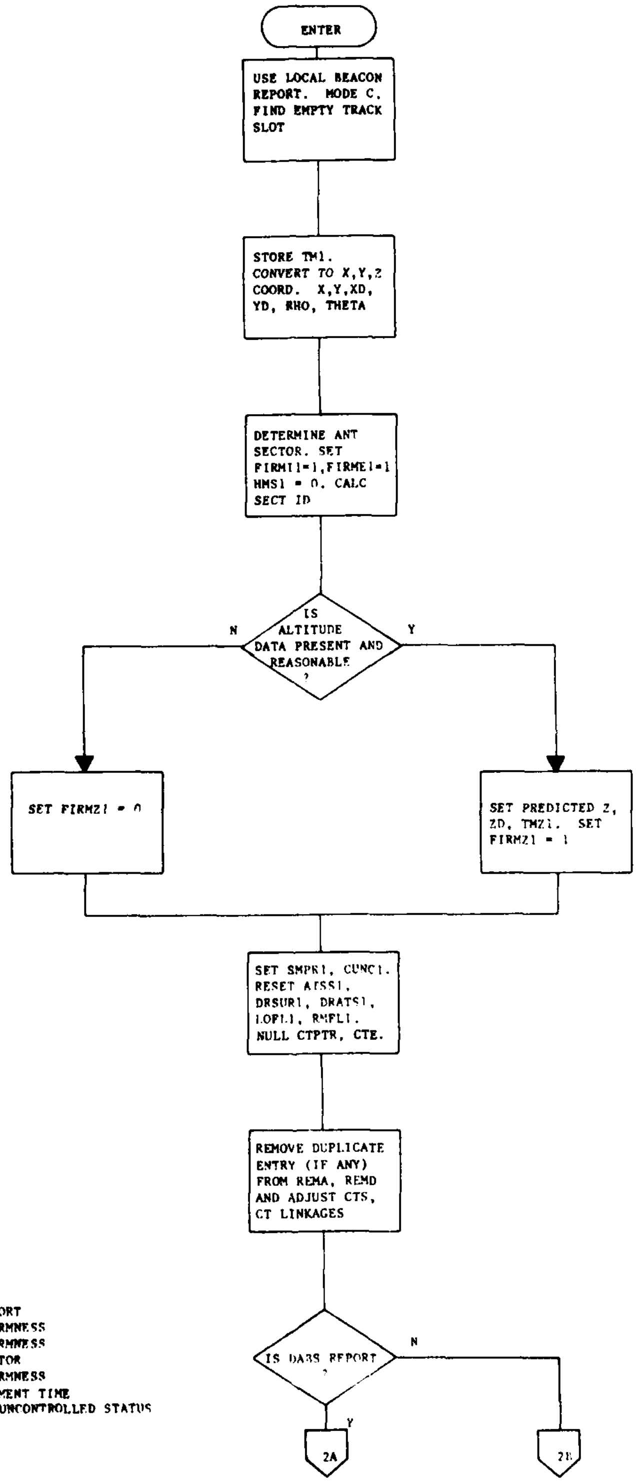
2. Determine and store this report's measurement time.

3. Convert the report coordinates to X, Y, Z. Determine and store the initial horizontal prediction estimates for external and internal positions, and velocities. Determine and store the initial predicted rho, theta search position.

The initial internal and external position predictions are set identical to the reported positions. Set the velocities to a small non-zero value. Turn rate stack is initialized for the track to be used in X, Y Smoothing Routine.

4. Determine the antenna sector in which this track lies and add it to the proper antenna sector list (with forward threading only).

5. Initialize the horizontal firmness (firmness control explained in Section 4.5.2) and the turn indicator.



TM1 - TIME OF REPORT
FIRMI - INTERNAL FIRMNESS
FIRME - EXTERNAL FIRMNESS
HMS1 - TURN INDICATOR
FIRMZ - VERTICAL FIRMNESS
TIMZ1 - ALT MEASUREMENT TIME
CUNC1 - CONTROLLED/UNCONTROLLED STATUS

FIGURE 4-5
TRACK INITIALIZATION ROUTINE (Page 1 of 2)

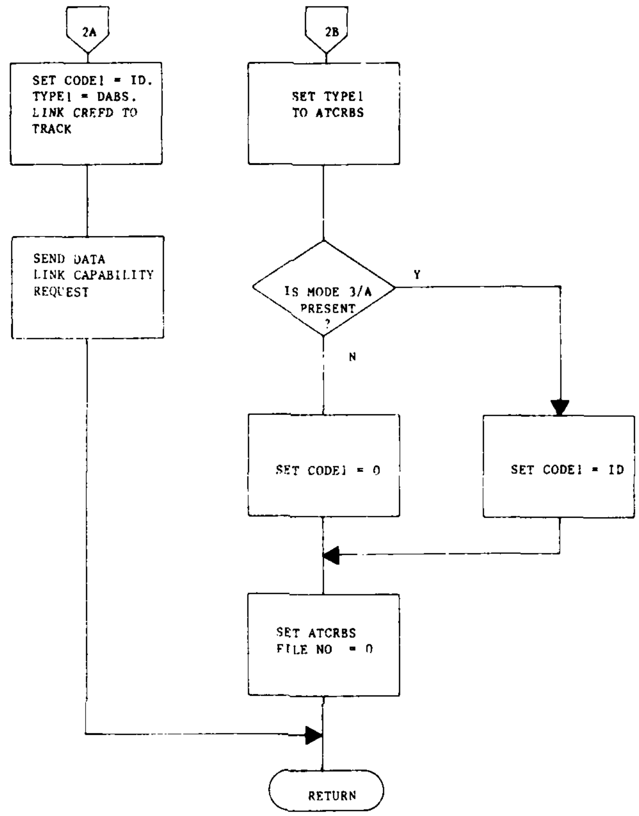


FIGURE 4-5
TRACK INITIALIZATION ROUTINE (Page 2 of 2)

6. Calculate the ATARS sector identification.

7. Check for altitude data, present and reasonable.

   a. If data is usable, set initial vertical position and set the velocity prediction to a small non-zero value. Set the altitude measurement time and initialize FIRMZ = 1.

   b. If data is not usable, set FIRMZ = 0.

8. Set the smooth/predict flag. Clear the ATARS service and drop flags, ATSS, DRSUR, DRATS and the data flags LOFL, RMFL.

9. Set the controlled/uncontrolled indicator according to the new report.

10. Clear REMA, REMD if this surveillance report is a duplicate.

11. Check the report source.

   a. If the report source is ATCRBS, set the track type to ATCRBS, and if Mode 3/A data is available insert it in CODE.

   b. If the report source is DABS, set CODE to this ID, set TYPE to DABS and form a new CREFD link to this track.

4.5 Track Processing

The Track Processing Task performs the final elimination of tracks which are not to be serviced by ATARS and track update processing. All surveillance reports have been associated with tracks or used to start new tracks in the Report Processing Task. Track processing accepts each report and calls the Track Update Routine (Section 4.5.1). All report correlation is accomplished in the DABS sensor and is accepted as being complete by ATARS.

The flow chart for the Track Processing Task is given in Figure 4-6. Input data for track processing consists of local or remote reports with remote times of measurement which have been stored with the associated track in CTS by report processing (one report, or none, per track).

Track processing operates once each time the local sensor antenna enters a new sector and processes tracks in particular sectors (relative to the antenna). The sectorization of CTS is accomplished by threading, which is updated as aircraft positions are repredicted.

The program is organized so that when the antenna enters sector n, all tracks in sector n-4 are processed. Then all tracks in sector n-20 are processed, (see the timing diagram, Figure 4-7). The sector gap from n to n-4 allows time for DABS sensor processing and transmission delays. The maximum delay for surveillance input reports is expected to be 3 sectors (3/8 second).

The primary function of track processing is to perform track updates in sector n-4 normally with local data, but if this is missing, to attempt remote data updates twice per scan in sectors n-4 and n-20. This double attempt allows timely use of remote reports. Also, late local reports are processed in sector n-20. Various processing flags and time checks are utilized to prevent too frequent updates or confusion because of sector changes.

The services performed are as follows:

1. Sector n-4 - First Pass Processing

   a. Index all tracks in this sector whose smooth/predict and antenna sector process flags are not set.

   b. If a report is not a null report, use this data and perform a track update (hit). This includes smoothing and prediction.

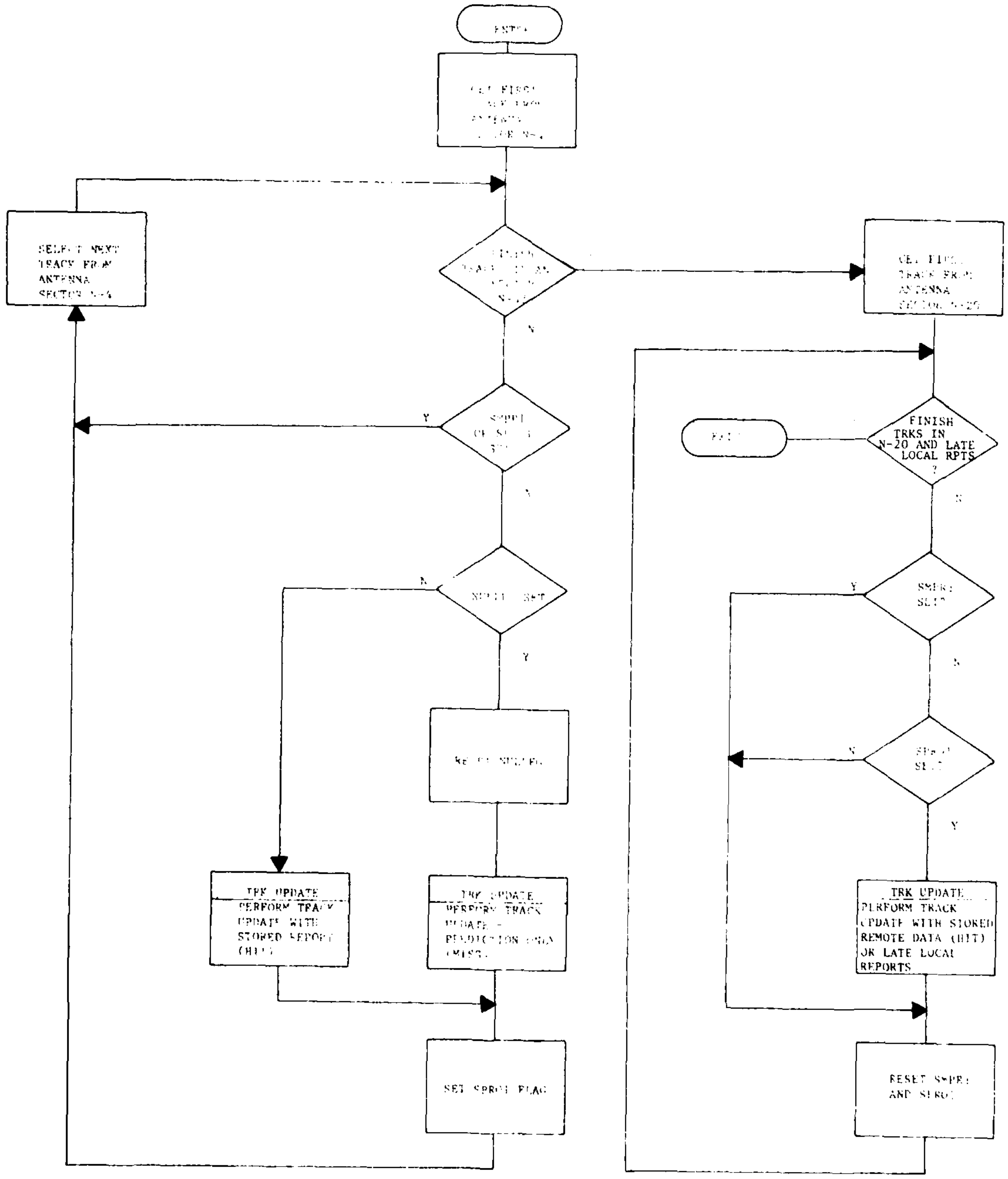
   c. If a null report has been stored, perform a track update (miss). This provides prediction only.

   d. Set the antenna sector process flag in the state vector.

2. Sector n-20 - Second Pass Processing (Remote Reports)

   a. Index all tracks in this sector and late local reports.

   b. For each track check whether remote data has been stored and that the smooth/predict flag is clear and the antenna sector process flag is set. If this is



SMPRI - SMOOTH/PREDICT FLAG
SPROI - ANTENNA SECTOR PROCESS FLAG
LOFLI - LOCAL DATA FLAG
RMFLI - REMOTE DATA FLAG

FIGURE 4-6
TRACK PROCESSING TASK

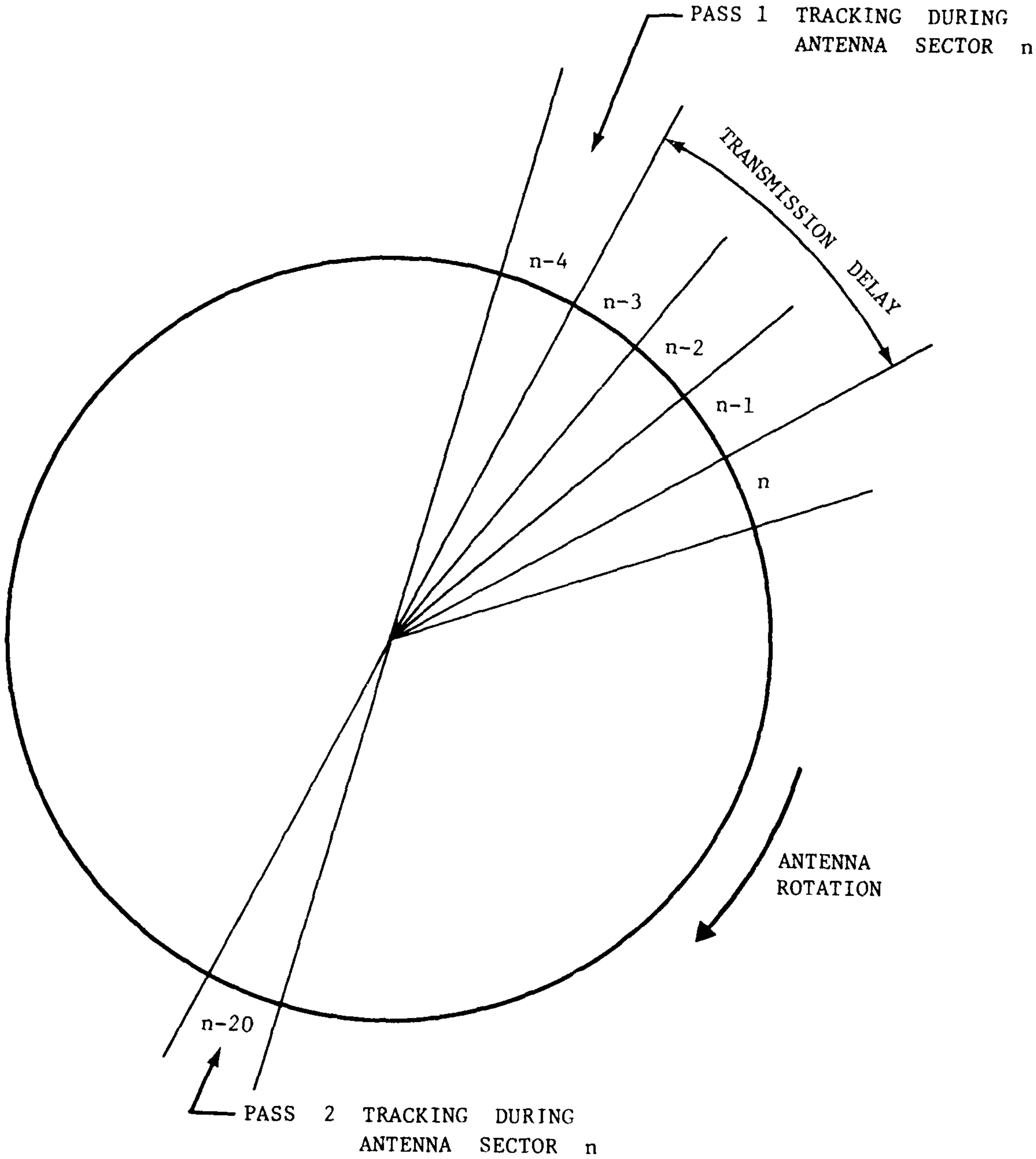


FIGURE 4-7
TRACKER TIMING AND SEQUENCE

true accept the remote data and perform a track update (hit) which includes smoothing and prediction. Also perform this step for late local reports. Otherwise, skip this step.

c. Clear smooth/predict and antenna sector process flags.

The flags used in this logic are maintained in the individual track state vectors as:

Remote data flag	= RMFL
Local data flag	= LOFL
Smooth/predict flag	= SMPR
Antenna sector process flag	= SPRO

4.5.1 Track Update

The Track Update Routine is depicted in Figure 4-8. This routine has two points of entry. One is used to process a track after a report has been selected (a hit); the other entry is used to process the track in final prediction only if the track report is a null (a miss). The main routine uses smoothing and prediction and performs other state vector update functions as well. Accessory bookkeeping operations affect the CREFA and CREFD files.

The following special services are performed for a hit.

1. Find the measurement time for the current report. If the report is local, this time is computed from the report azimuth and the antenna position/rate estimates. If the report is remote, the time has been determined by the Report Processing Task and stored as TMR (see Section 4.7). The time of the current report, TM_{next}, should be set equal to TMR. DLOUT (parameter indicating that the local sensor lost data link contact with the aircraft on the most recent scan) is initially set for every pass through this routine. It is only reset if a local DABS report is used.

2. Correct the previous predictions for this track to the current measurement time, if necessary. The predictions are for an anticipated time of local data measurement. Thus, if this report is local, no correction will ordinarily be required. However, remote data will be measured at quite different times, and the previous predictions must be corrected. Correction is accomplished by shifting the X, Y

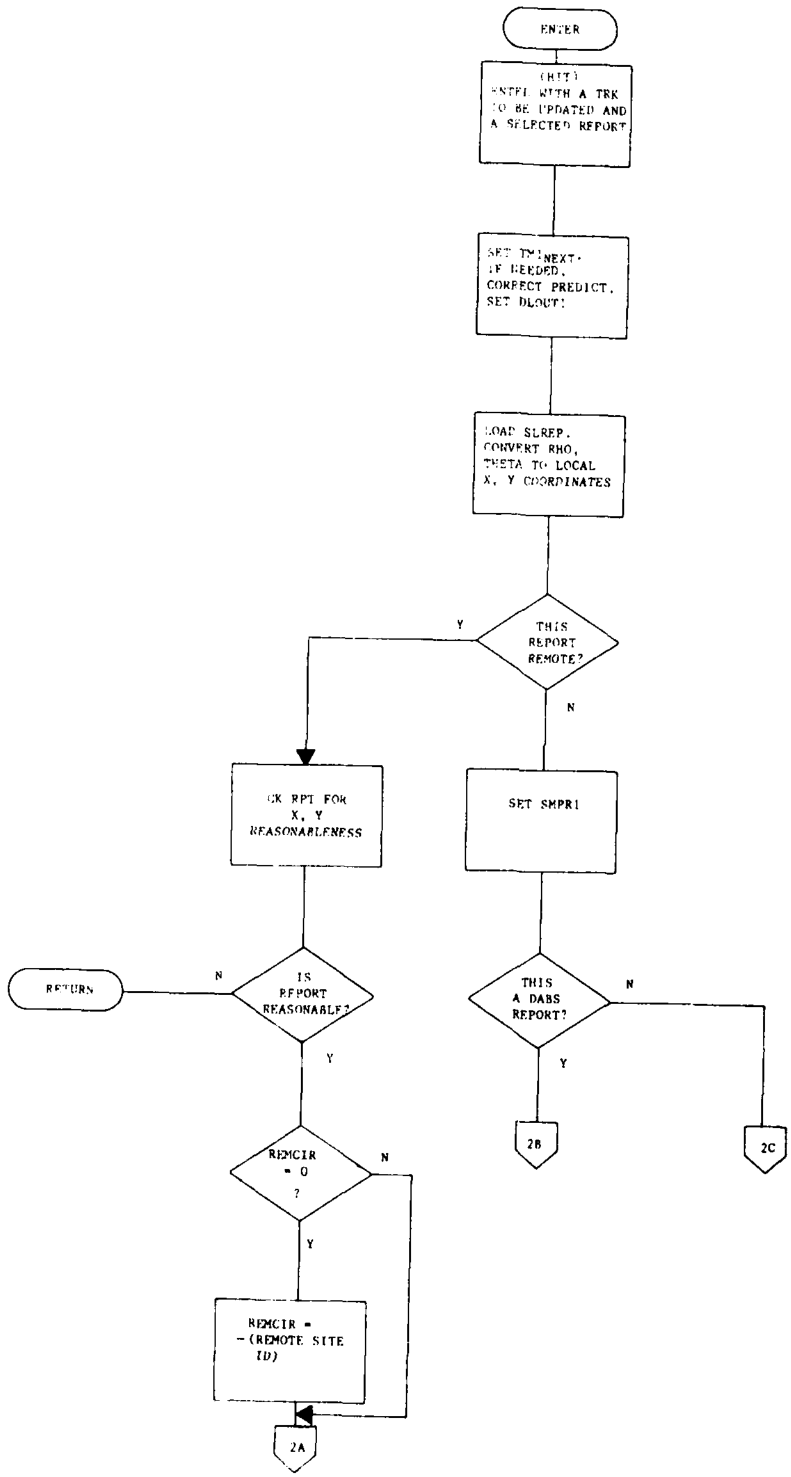
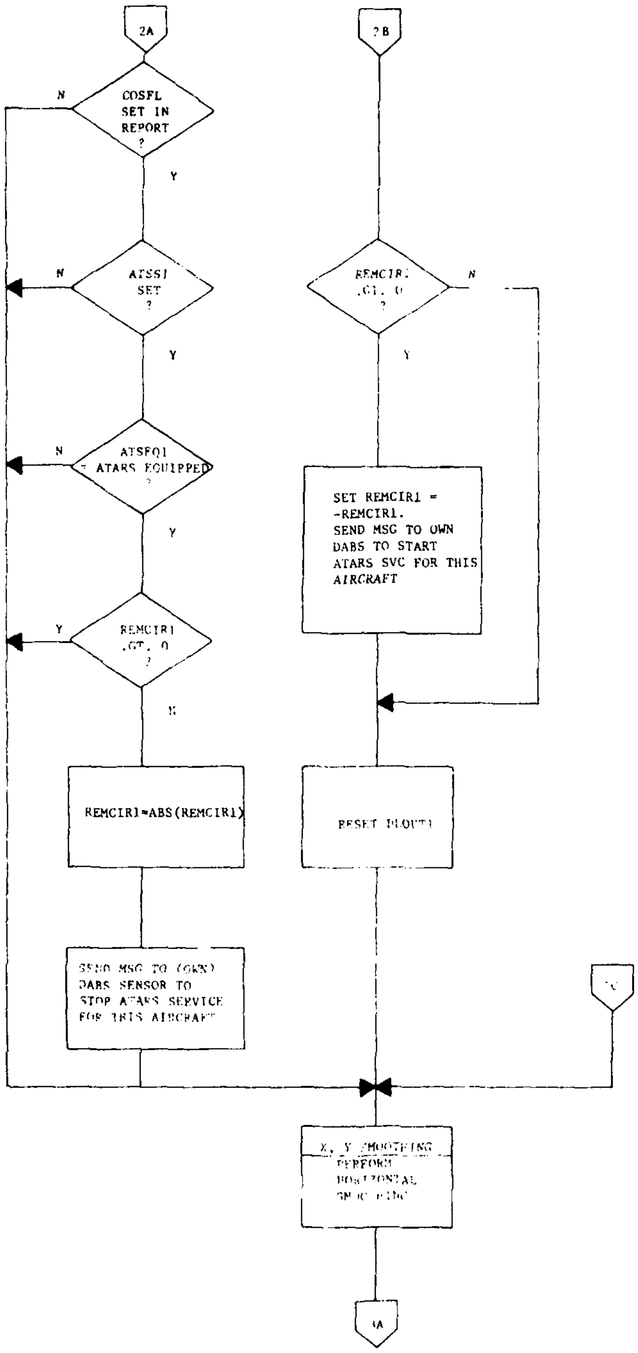
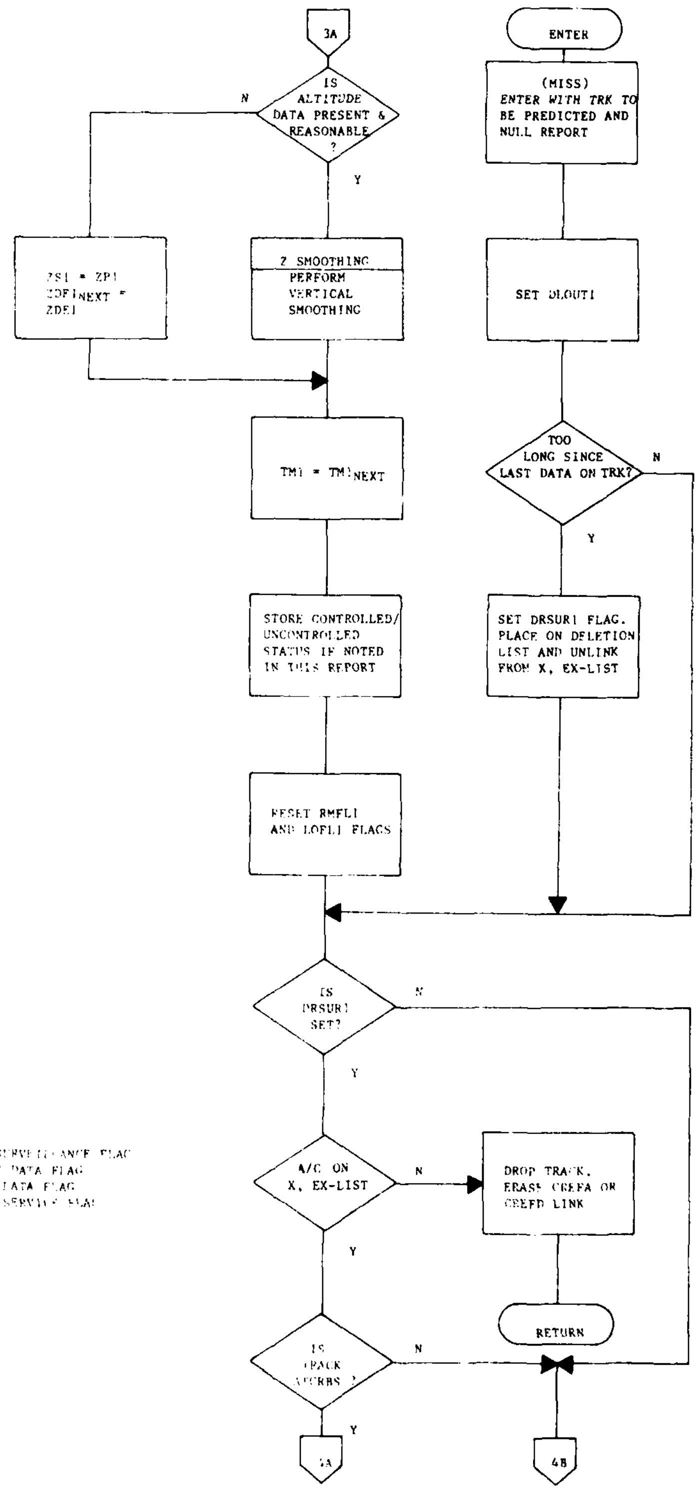


FIGURE 4-8
TRACK UPDATE ROUTINE (Page 1 of 5)



OSCFL - LIFE OF ONE SCAN FOR [illegible]
COSFL - CONE OF SILENCE FLAG

FIGURE 4-8
TRACK UPDATE ROUTINE (Page 2 of 5)



DRSURI - DROP SURVEILLANCE FLAG
RMFLI - REMOTE DATA FLAG
LOFLI - LOCAL DATA FLAG
ATSSI - ATARS SERVICE FLAG

FIGURE 4-8
TRACK UPDATE ROUTINE (Page 3 of 5)

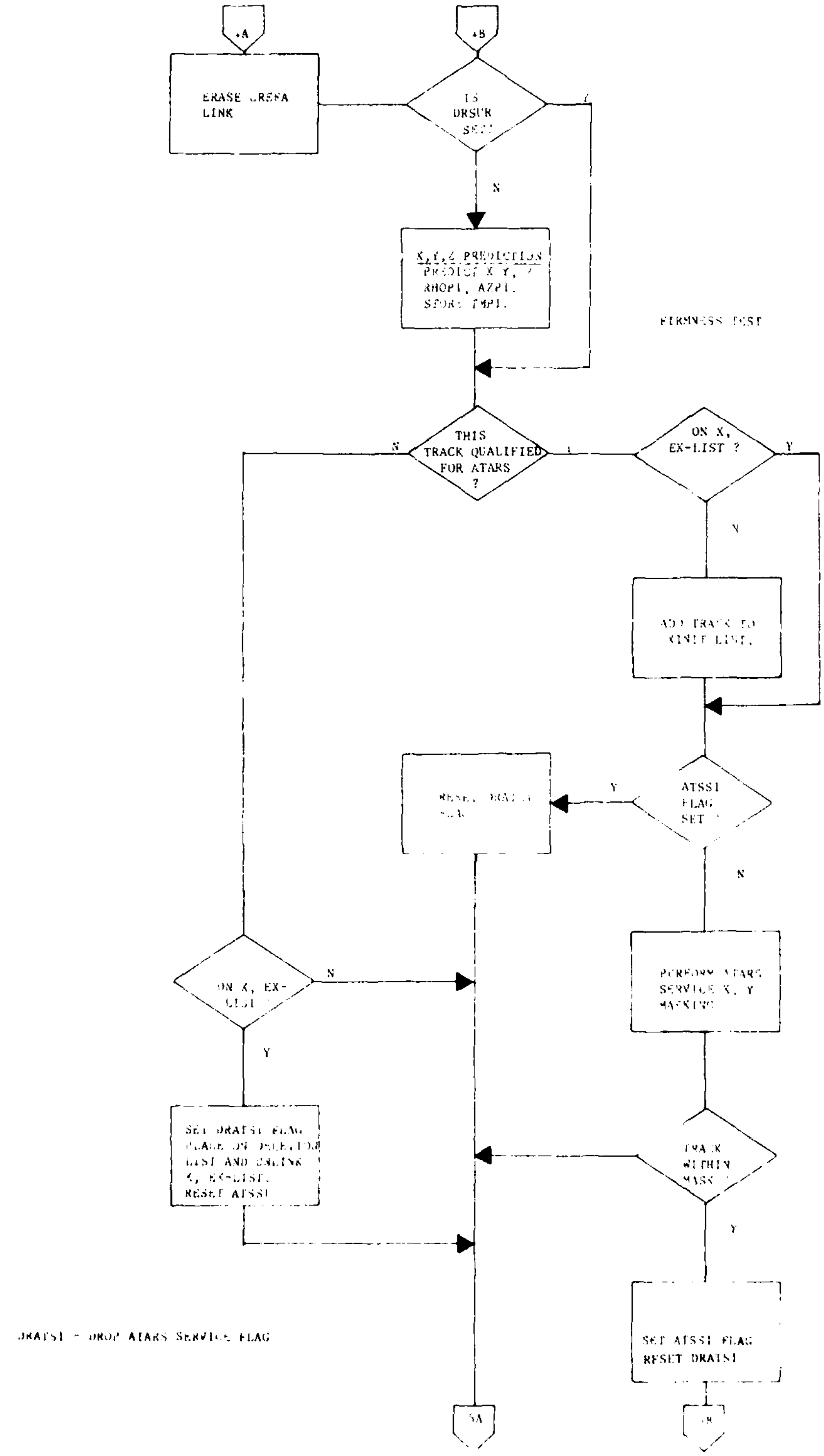
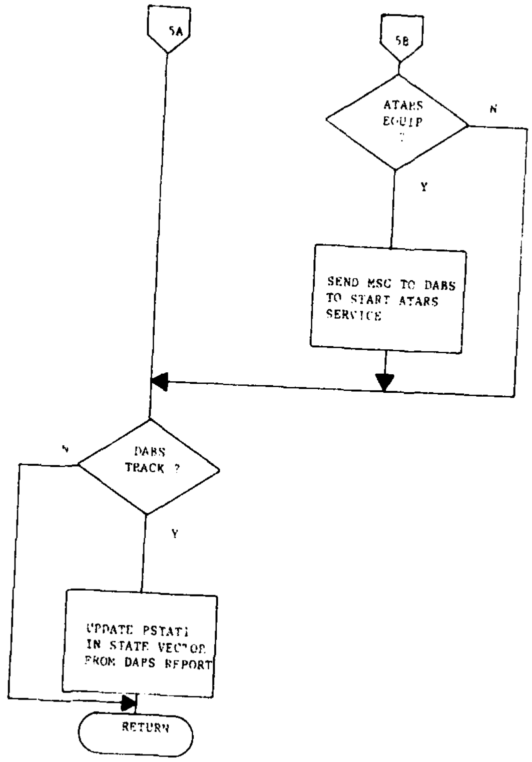


FIGURE 4-8
TRACK UPDATE ROUTINE (Page 4 of 5)



PSTATI = LOCAL SITE PRIMARY/SECONDARY

FIGURE 4-8
TRACK UPDATE ROUTINE (Page 5 of 5)

and Z predicted coordinates by the time difference (TMP - TMR) times the internal X, Y and Z velocity estimates. Both internal and external predictions will be affected (see Section 4.6).

3. Coordinate convert rho, theta data to the local X, Y system. Conversion of local data involves slant range correction as indicated in Figure 4-1. For remote reports a full remote to local system conversion must be used. These conversions utilize the altitude measurement if present. Otherwise, the estimated altitude is used. In cases where neither is available, a nominal value of ZNOM will be assumed. The slant range for both local and remote surveillance reports must be transferred into SLREPS before any coordinate conversions are made to the data.

4. If this report is local, set the smooth/predict flag. If the report is a DABS report, check the identity of the remote site in the CIR using REMCIR. If REMCIR is positive, send a message to this ATARS site to stop sending CIR data to this aircraft and inform the local DABS sensor to start ATARS service for this aircraft. If REMCIR is negative, then the remote site identified in the CIR is where data may be requested. Reset the DLOUT flag in the state vector of this aircraft.

5. If this report is remote, check the measurement X, Y position against the external prediction (corrected) for reasonableness. If not reasonable, return without an update. If the cone of silence flag is set (COSFL), the ATARS service flag is set (ATSS), the aircraft is ATARS equipped (ATSEQ), and REMCIR is negative (remote site identified from which data will be requested) a message is sent to the site requesting CIR data for this aircraft. Sent along with this message is own-site ATARS identification and the state of remote site life scan flag (OSCFL). Inform the local DABS sensor to stop ATARS service for this aircraft.

6. Perform X, Y smoothing with the ATARS horizontal smoothing algorithm.

7. If altitude data is present with this report, check it for reasonableness (with respect to altitude limits and prediction). If reasonable, perform Z smoothing with the ATARS vertical smoothing algorithm.

8. Replace the old X, Y measurement time, TM, by the new report time, TM_{NEXT}.

9. Set the controlled/uncontrolled flag according to the new DABS report.

10. Clear the local and remote data flags; LOFL, RMFL.

The following special services are performed for a miss.

1. Set the DLOUT flag in the state vector of this aircraft. The flag will not be reset for a miss.

2. If present time minus TM is greater than TDROP, then set the drop flag (DRSUR), place aircraft on deletion list and unlink from X/ EX-list; otherwise, ignore.

The following common services are performed for either a hit or miss after the special services have been completed.

1. If the drop flag, DRSUR, is set, test the ATARS service flag, ATSS. If this is not set, the track is dropped and its cross-reference links (CREFA or CREFD) are erased. If ATSS is set, the State Vector Deletion Task has responsibility for the drop; however, an ATCRBS track cross-reference (CREFA) must be deleted here.

Dropping a track here consists of simply rethreading it onto the empty list.

2. Predict track horizontal and vertical positions to the estimated time of next local data for this track using the ATARS prediction algorithm. Compute the predicted rho, theta and store. Store the prediction time, TMP.

3. Test the track for ATARS qualification. (NOTE: Firmness control is discussed in Section 4.5.2). Tracks are qualified for ATARS service if they have:

a. FIRMI .GE. FESTAB
b. FIRMZ .NE. 0
c. (clock time - TMZ) .LE. TMZMAX

If the track is not qualified, see if track is on the X, EX-list. If true, set the drop service flag, (DRATS), place the aircraft on the deletion list and unlink from X/ EX-list; otherwise, ignore.

If the track is qualified, see if on X, EX-list. If not in either list place in the XINIT list for the Aircraft Update Processing Task by use of NEXTX. If track is on X, EX-list and ATSS is not already set, test the track position estimates (external prediction; XP, YP, ZP) to determine whether the track lies within the ATARS service area. This is accomplisned by a geographical area determination which utilizes an X, Y masking procedure. This X, Y mask is defined as the ATARS mask service area as shown in Figure 4-4. The mask is divided into seam sectors which are defined by rho, theta limitations.

If the track is within the area, set the ATSS flag. The tracks are placed on the appropriate X or EX-list in the aircraft update task. If the aircraft is ATARS equipped, a message is sent to the DABS sensor to start ATARS service for this track. For all DABS tracks, the primary/ secondary status of the track is recorded in the state vector (PSTAT).

4.5.2 Firmness Control

The ATARS tracking system uses the method of firmness controlled smoothing parameters (see Table 4-1). Firmness values for each track are adjusted in accordance with its record of correlation success (see Table 4-2). The firmness table construction and use for the ATARS tracking system differs from its Augmented ARTS III counterpart in several ways. The following features are present.

1. Fewer levels have been assigned and the alpha, beta smoothing parameter values of these levels have been altered.

2. Together with alpha and beta an additional threshold parameter, THK, has been added to adjust ATARS cross-track smoothing thresholds. (The notation (THK = ***) means that the ATARS turn detection should be disabled.)

3. Three firmness values, FIRMI, FIRME and FIRMZ, are maintained on each track. Each uses the same lookup table to select parameters for internal X, Y, for external X, Y, or for altitude smoothing. FIRMI is used for THK lookup.

4. These firmness values step up or down depending on the success or failure of attempts to correlate on a particular scan. The adjustments are made after the previous firmness levels have been used for lookup. Nominal adjustments,

TABLE 4-1

SMOOTHING PARAMETERS VS. FIRMNESS

FIRM	ALFA	BETA	THK
0	1.000	0.000	-
1	1.000	1.000	***
2	1.000	1.000	***
3	.833	.700	3.60
4	.700	.409	2.00
5	.600	.270	1.50
6	.524	.192	1.26
7	.464	.144	1.12
8	.417	.112	1.03
9	.400	.100	1.00

*** Indicates a very large positive value which disables turn detection.

TABLE 4-2

FIRMNESS TABLE STEP CONTROL

FIRM (CURRENT VALUE)	CORRELATION SUCCESS FIRM (NEXT VALUE)	CORRELATION FAILURE FIRM (NEXT VALUE)
0	2	0
1	3	1
2	3	2
3	4	2
4	5	2
5	6	3
6	7	4
7	8	5
8	9	6
9	9	7

Note: Additional maximum limits may be applied to firmness levels.

which are common to all three firmness values, are further subject to absolute assigned maximum firmness limits. Nominally,

$$FIRMI_{max} = 9$$
$$FIRME_{max} = 4$$
$$FIRMZ_{max} = 7$$

These values cannot be exceeded during stepping. Note that a successful rho, theta correlation does not necessarily result in a successful altitude correlation so that FIRMZ does not necessarily increase with FIRMI and FIRME. Altitude reports may be missing or, if present, they must pass a reasonableness test before they are accepted for smoothing.

5. When a track is initiated, FIRMI and FIRME are inserted at level 1. Similarly, if altitude data on this new track has been received, FIRMZ is also initialized at 1. If no altitude data has been received, set FIRMZ = 0.

6. A track is terminated when the time interval between the current time and the time of the last successful horizontal reply (represented by TM) exceeds the threshold value TDROP.

7. All turning track firmness levels used in ARTS III have been deleted.

4.6 Track Estimation

Track estimation consists of two processes: smoothing, in which a track's current data is combined with a previously made prediction to achieve an improved estimate of the current state, and prediction, in which the current smoothed state is extrapolated one scan ahead to assist correlation and prepare for the next smoothing step. Figure 4-9 illustrates turn sensing, smoothing and prediction based on the current positions and velocities.

Smoothing and Prediction Routines are called in the main Track Update Routine. The essential data communicated to the smoothing algorithm is:

a. the track to be processed,
b. the report to be used for smoothing,
c. estimates of antenna position and rate.

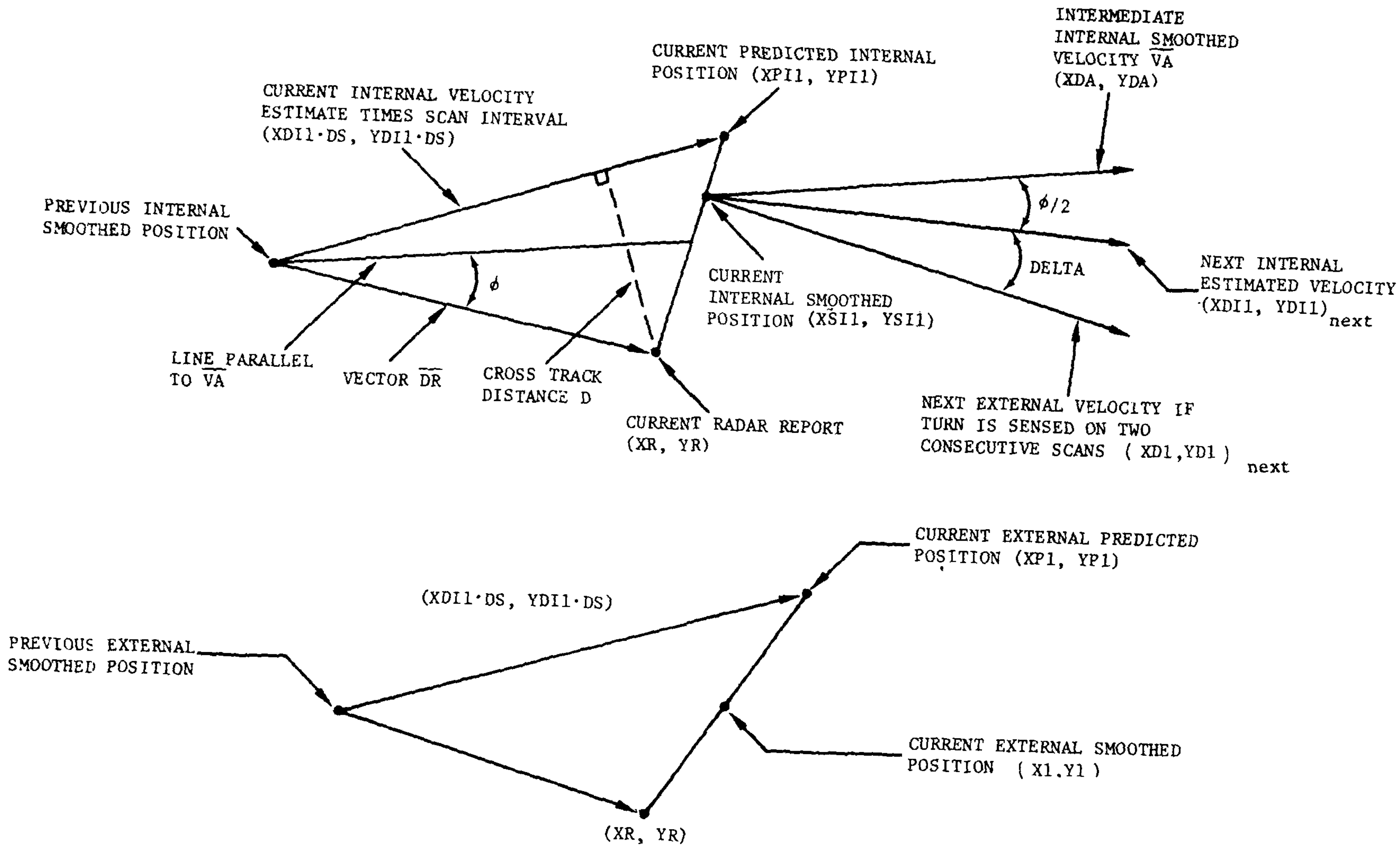


FIGURE 4-9
VARIABLES AND CONSTRUCTIONS FOR ATARS .
TRACK SMOOTHING

The prediction algorithm requires only the first and third items. Both algorithms modify the contents of the track state vector. In both smoothing and prediction, reference is made to internal and external position and velocity coordinates. Internal refers to those positions and velocities used internal to the Track Processing Task. External includes all positions and velocities used elsewhere in the ATARS tasks but generated in the Track Processing Task.

4.6.1 Smoothing

The ATARS track Smoothing Routine is designed to provide vertical velocity information and improved knowledge of aircraft heading during turns. Thus, ATARS conflict detection and conflict resolution may be performed more effectively for maneuvering aircraft than has been possible with previous ATC algorithms.

Horizontal (X, Y) positions and velocities are smoothed by the well-known alpha, beta technique until a maneuver is sensed.

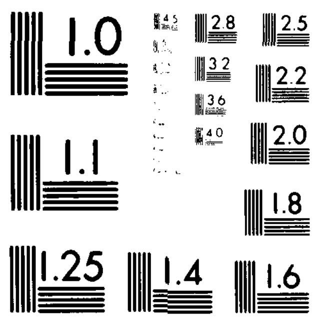
The cross-track deviation (data report distance from the line of the predicted track vector) is compared with an assigned threshold to detect a turn. If a turn is detected, the turn rate (W) is computed from a modified cross track deviation computed from the oldest of three previous smoothed positions and velocities. Figure 4-10 illustrates turn rate computation (in relation to Figure 4-9) using historical positions and velocities. Figure 4-11 illustrate the turn rate computations used for the advisory service in ATARS. Maneuvering tracks are smoothed by a special method which includes track-oriented geometric calculations. The following implementation avoids use of trigonometric functions wherever possible. Vertical (Z) positions and velocities are smoothed by an alpha, beta filter (without modification during maneuver).

These smoothing operations are controlled by three important CTS track firmness parameters, FIRMI, FIRME, and FIRMZ, which are maintained by the correlation program in accord with the record of correlation successes and failures. Table 4-1 shows how the various Smoothing Routine parameters vary with these firmness values (denoted generically by FIRM). (The level zero is restricted to FIRMZ and requires only alpha, beta parameters.) The X, Y Smoothing Routine is illustrated in Figure 4-12.

Before the X, Y Smoothing Routine is entered, the measured range and azimuth are converted to Cartesian XR, YR components. CTS contains the predicted internal position XPI1, YPI1, and

AD-A094 195 MITRE CORP MCLEAN VA METREK DIV F/G 1/5
AUTOMATIC TRAFFIC ADVISORY AND RESOLUTION SERVICE (ATARS) MULTI--ETC(U)
OCT 80 R H LENTZ, W D LOVE, N S MALTHOUSE DOT-FA80WA-4370
UNCLASSIFIED MTR-80W00100-REV-1 FAA-RD-80-3-REV-1 NL

2 of 6
AD A
094195



MICROCOPY RESOLUTION TEST CHART

NATIONAL

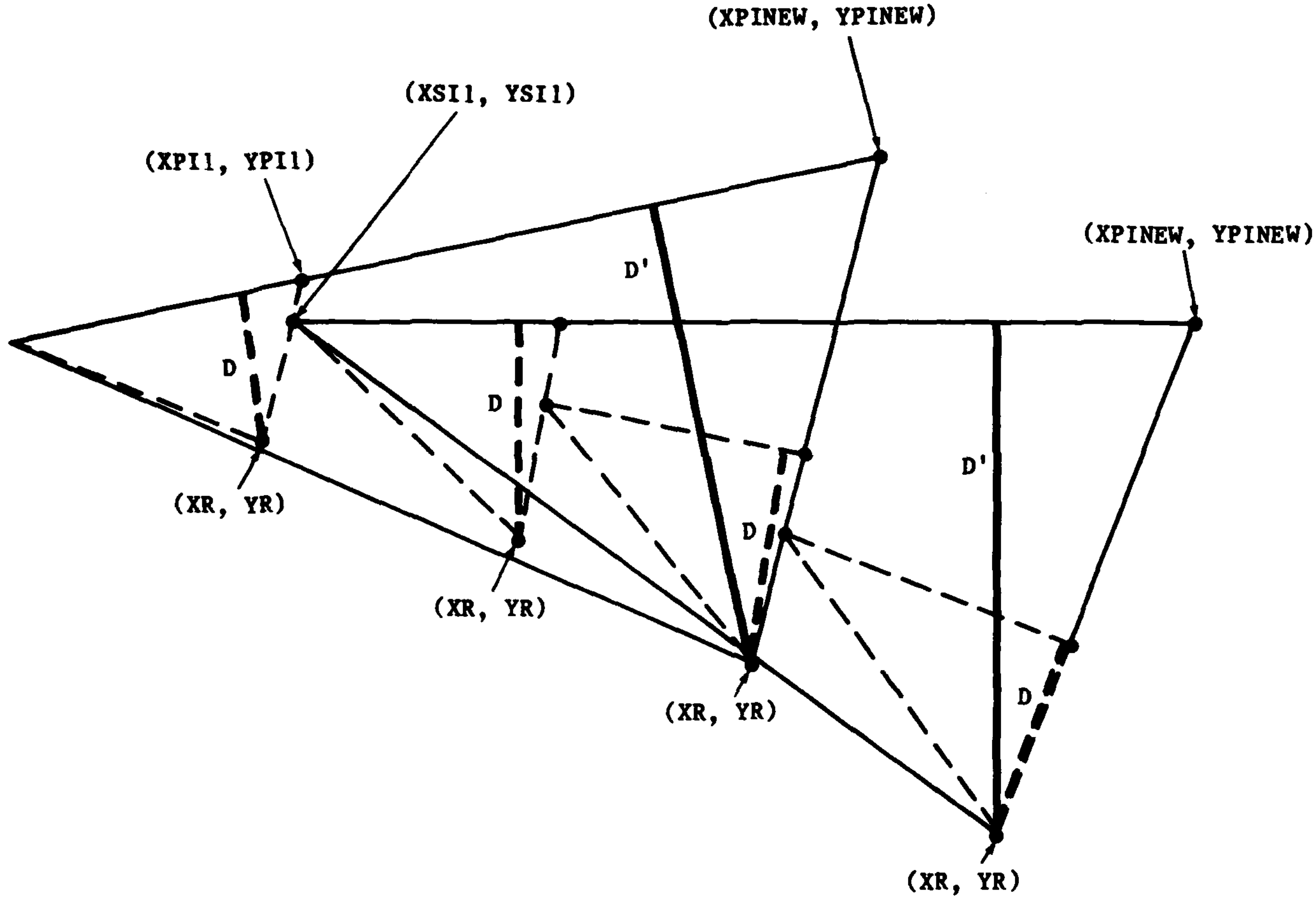
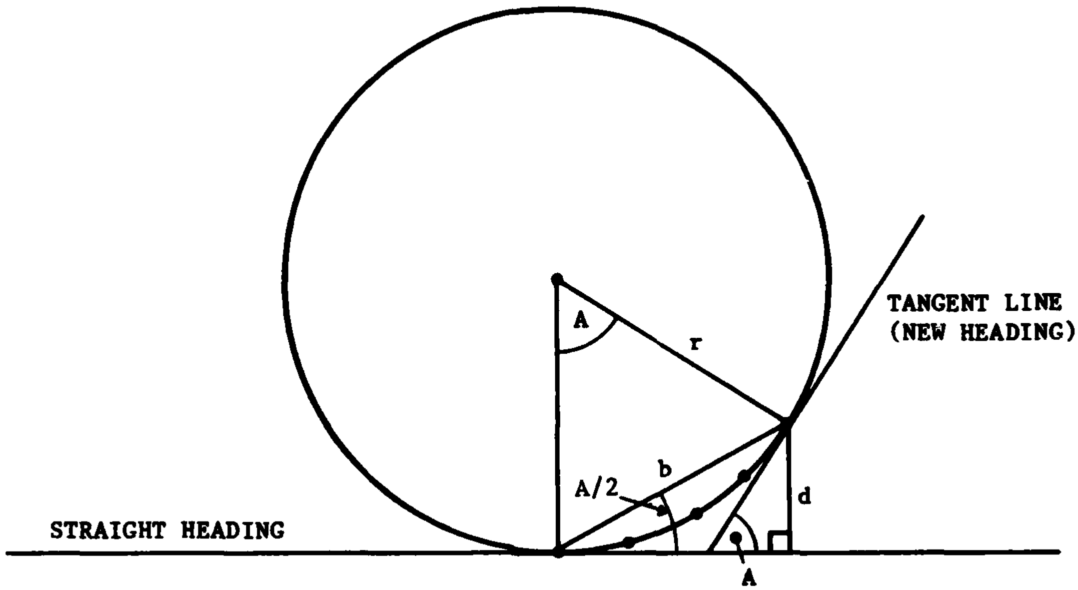


FIGURE 4-10
PREDICTION AND CROSS TRACK DEVIATION USING HISTORICAL POSITIONS AND VELOCITIES



$$\begin{aligned}
\text{SIN } A &= b/r \\
b &= 2r \text{ SIN } A/2 \\
d &= b \text{ SIN } A/2 \\
&= 2r \text{ SIN}^2 A/2 \\
\text{approx.} &= 2r\, A^2/4 \text{ FOR SMALL } A
\end{aligned}$$

$A = wt$ $\qquad$ t = TIME FOR n SCANS

$rA = vt$ $\qquad$ v = VELOCITY

$$\begin{aligned}
d &= 2(vt)wt/4 \\
&= 1/2\ vwt^2
\end{aligned}$$

$w = 2d/vt^2$ $\qquad$ TURN RATE

SUBSTITUTING FOR d AND v, THE TURN RATE EQUATION IS:

$W = 2CTDA/(XDIOLD^2+YDIOLD^2) \quad * \ (DT+ST)^2$

FIGURE 4-11
TURN RATE COMPUTATION FOR ADVISORY SERVICE

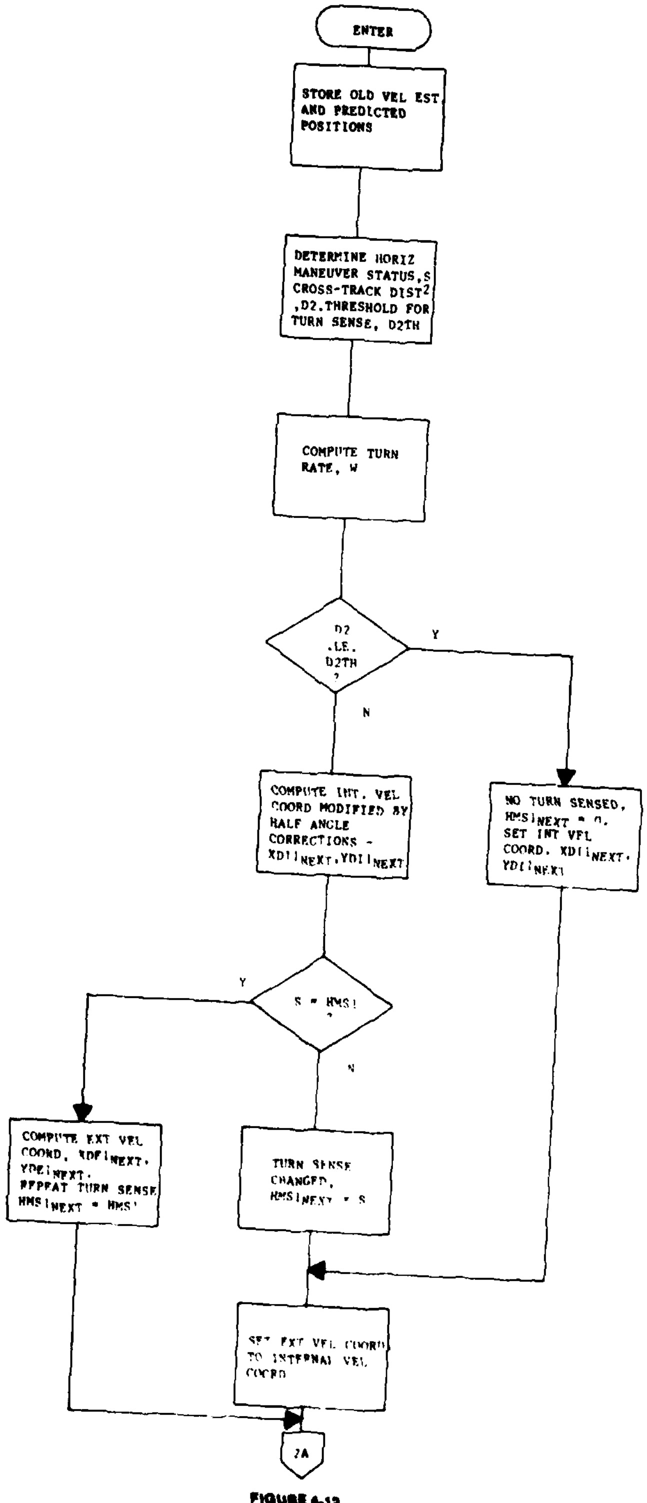


FIGURE 4-12
X, Y SMOOTHING ROUTINE (Page 1 of 2)

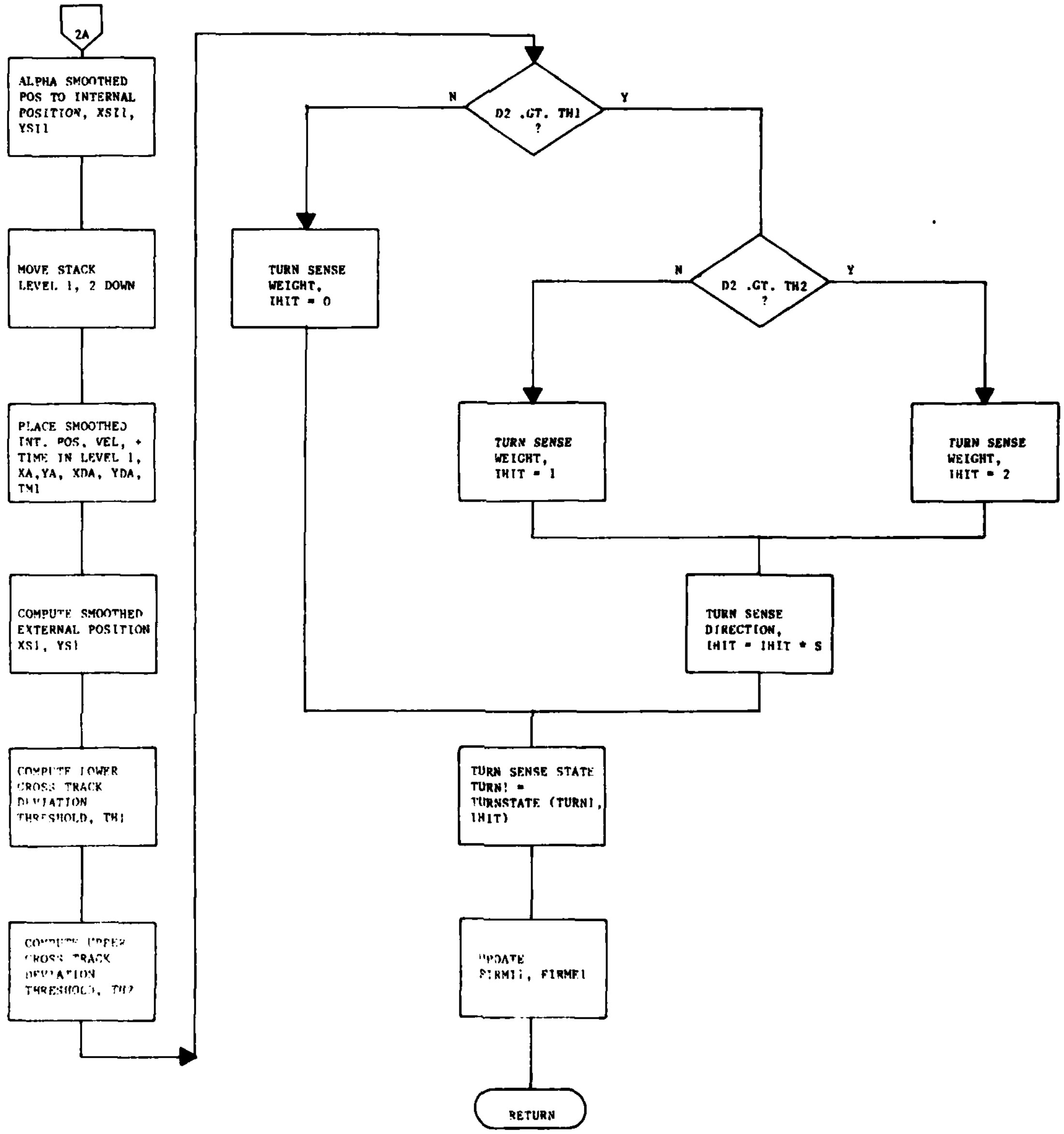


FIGURE 4-12
X, Y SMOOTHING ROUTINE (Page 2 of 2)

velocity, XDI1, YDI1, estimates for the current predicted data time, TMP1. CTS also contains up to three previous smoothed internal positions, velocities, old data times, and the special predicted positions used for the turn rate. For an update with local data, TMP1 is sufficiently close to the true measurement time that these predictions may be directly compared with the measurements. For an update with remote data, the predictions XPI1, YPI1 are first corrected to the remote measurement time by using the velocities XDI1, YDI1 and applying the time difference TMR1-TMP1.

Several quantities to be used in the computation of the turn rate are initialized in the Track Initialization Routine, and are available in the state vector. These variables are updated in the X, Y Smoothing and Prediction Routines. These parameters are outlined below.

Last predicted internal velocity:

XDIOLD = XDI1
YDIOLD = YDI1

Last predicted internal position:

XPINEW = XPI1
YPINEW = YPI1

Time on the stack:

ST = 0

The stack time is initialized in the Track Initialization Routine and stored in CTS. The stack time is computed each scan in the Track Processing Task.

Then define the internal deviation vector DI as:

$$\overline{DI} = \begin{bmatrix} DIX \\ DIY \end{bmatrix} = \begin{bmatrix} XR - XPI1 \\ YR - YPI1 \end{bmatrix} \quad \text{and}$$

$$\overline{CTDI} = \begin{bmatrix} CTDIX \\ CTDIY \end{bmatrix} = \begin{bmatrix} XR - XPINEW \\ YR - YPINEW \end{bmatrix}$$

Let the elapsed time since the last X, Y data was received on this track be DT. This time difference is calculated from the last data time, TM1, stored in CTS and the new data time. New data time for local reports is determined here from the measured azimuth and the antenna motion estimates. For remote reports it is determined in report processing and stored with the report (TMR1).

Then ALFA, BETA are selected through FIRMI, and the smoothing equations produce the intermediate estimated coordinates designated XA, YA, XDA, YDA as follows:

$$XA = XPI1 + ALFA * DIX$$

$$YA = YPI1 + ALFA * DIY$$

$$XDA = XDI1 + BETA * DIX/DT$$

$$YDA = YDI1 + BETA * DIY/DT$$

The next step is to sense for turns. Let

$$A = DIX * YDI1 - DIY * XDI1$$

$$CTDA = CTDIX * YDIOLD - CTDIY * XDIOLD$$

$$S = Sign\ (A)$$

$$B = XDI1^2 + YDI1^2$$

The cross track distance, D, used for turn sensing is

$$D = A/SQRT(B)$$

The square root can be avoided by dealing with the square of this distance, D2.

$$D2 = A^2/B$$

Let D2TH be a threshold by which D2 is measured to sense a turn. Then, if D2 .GT. D2TH and S is negative, a left turn is sensed. If D2 .GT. D2TH and S is positive, a right turn is sensed.

The threshold is computed as a function of track range, speed, orientation and the data source used for this update. It is

further modified by the factor THK which depends on FIRMI. The calculation of D2TH is accomplished through two intermediate quantitites, DTHA and DTHB:

$$D2TH = THK * (DTHA + DTHB * (XA * XDA + YA * YDA)^2/(V2A * R2A))$$

where

$$R2A = XA^2 + YA^2$$

$$V2A = XDA^2 + YDA^2$$

Physically, DTHA is the square of the threshold which is appropriate for testing the radial deviations of a track moving tangentially to the radar. DTHA + DTHB is the square of the threshold appropriate for testing tangential deviations of a track moving radially. The factor multiplying DTHB is the square of the cosine of the angle between the track direction and the radius vector from the radar. Since the predicted range is available from CTS, it may also be used with sufficient accuracy in place of the R2A computation above. The quantities, DTHA and DTHB, are determined from sensor error standard deviations and track speed by the empirical formulas:

$$DTHA = (3.1 * STDA + 1.35 * SQRT\ (V2A))^2$$

$$DTHB = (3.1 * STDB + 1.35 * SQRT\ (V2A))^2 - DTHA$$

The speed estimate, SQRT(V2A), must be expressed in knots for this calculation when the other quantities are in feet.

The sensor error parameters, STDA and STDB, are, respectively, the radial and tangential data error standard deviations as specified in Reference 1. A typical parameter set for each data source is listed in Table 4-3. Tangential parameters generally depend on the track-range, SQRT(R2A). Since remote data is not oriented conveniently in the local sensor system, a pessimistic, isotropic assignment is made.

When a turn is sensed, a correction in the direction of the sensed turn is made in the heading of the aircraft. Let DR be the vector

$$\overline{DR} = \begin{bmatrix} DRX \\ DRY \end{bmatrix} = \begin{bmatrix} XDI1 * DT + DIX \\ YDI1 * DT + DIY \end{bmatrix}$$

TABLE 4-3

THRESHOLD PARAMETERS IN FEET

SOURCE	STDA	STDB[1]
Local DABS Beacon	150	.002 * SQRT (R2A)
Local ATCRBS Beacon	180	.002 * SQRT (R2A)
Local Radar	215	.004 * SQRT (R2A)
Remote Beacon	500	500

1 The range, SQRT(R2A), should be expressed in feet.

and VA the vector

$$\overline{VA} = \begin{bmatrix} XDA \\ YDA \end{bmatrix}$$

The magnitude of this correction is half of the angle between vectors DR and VA, except when this angle exceeds some threshold, TTH, in which case the correction is limited to TTH/2. (It is assumed that the parameter, TTH will be less than 90^{o}). Let phi be the angle between vectors DR and VA and let CT2 = $\cos^2$(TTH).

Define

$$C = DRX * XDA + DRY * YDA$$

$$P = Sign(C)$$

Then

$$CP2 = \frac{C^2}{(DRX^2 + DRY^2) * V2A}$$

Define

$$CP = SQRT(CP2)$$

Let sin (abs(phi)/2) = SPD2 and cos (abs(phi)/2) = CPD2. Where abs means the absolute value of the parameter.

$$SPD2 = SQRT((1-CP)/2)$$

$$CPD2 = SQRT((1+CP)/2)$$

Let delta theta be the absolute value of the heading correction and let SDT = sin (delta theta) and CDT = cos (delta theta). Let STD2 = sin(TTH/2) and CTD2 = cos(TTH/2). Then,

$$\left.\begin{array}{l} SDT = STD2 \\ CDT = CTD2 \end{array}\right] \quad \text{if } P * CP2 \text{ .LE. } CT2$$

$$\left.\begin{array}{l} SDT = SPD2 \\ CDT = CPD2 \end{array}\right] \text{ otherwise}$$

The new estimated internal velocity coordinates are:

$$\left.\begin{array}{l} XDI1_{next} = XDA * CDT + S * YDA * SDT \\ YDI1_{next} = YDA * CDT - S * XDA * SDT \end{array}\right] \text{ if D2 .GT. D2TH}$$

$$\left.\begin{array}{l} XDI1_{next} = XDA \\ YDI1_{next} = YDA \end{array}\right] \text{ if D2 .LE. D2TH}$$

When a turn has been sensed in the same direction on two consecutive updates, an additional heading correction of magnitude, DELTA, is applied in the direction of turn. Let SDEL = sin(DELTA) and CDEL = cos(DELTA).

The final external velocity coordinates, designated XDE1 and YDE1, used as a source of the coordinates in ATARS detection and resolution are:

$$XDE1_{next} = XDI1_{next} * CDEL + S * YDI1_{next} * SDEL$$

$$YDE1_{next} = YDI1_{next} * CDEL - S * XDI1_{next} * SDEL$$

if a turn is sensed on two consecutive updates, or

$$XDE1_{next} = XDI1_{next}$$

$$YDE1_{next} = YDI1_{next}$$

otherwise.

Note that the DELTA correction affects the data used for detection and resolution, but does not influence the internal tracker velocities, and, hence is not propagated into the future.

The smoothed internal position estimates are:

XSI1 = XA

YSI1 = YA

XSI1 and YSI1 are local variables and are processed further by prediction which occurs later.

The horizontal maneuver status indicator, HMS1, stores the turn indication for use on the next update. It is set to zero during track prediction if the predicted time of the miss data is later than THMS beyond the last data time.

Let XP1, YP1 be the external estimates used in ATARS. These are position predictions for the current data time, but distinct and separate from the internal estimates. Define the external deviation vector DE as:

$$\overline{DE} = \begin{bmatrix} DEX \\ DEY \end{bmatrix} = \begin{bmatrix} XR - XP1 \\ YR - YP1 \end{bmatrix}$$

Here, too, for remote data a preliminary correction is applied to XP1, YP1 using XDI1, YDI1 and the time difference TMR1-TMP1.

After ALFA is selected through FIRME, the smoothed estimates XS1, YS1 are produced by the operation:

XS1 = XP1 + ALFA * DEX

YS1 = YP1 + ALFA * DEY

XS1 and YS1 are local variables and are processed further by prediction which occurs later.

Both internal and external position estimates are propogated into the future, but positions predicted for turn rate computations (see Figure 4-11) are completely independent and are not propagated into the future. The reason for these two types of estimates is that the internal positions are designed to provide effective turn sensing while the external estimates provide more accurate actual positions for ATARS and track data correlation. External velocities are used for correction.

The Detect Task and Resolution Evaluation Routine use the turn status as determined by the following logic. The turn sensing algorithm will have seven states (noted in Table 4-4) representing different degrees of confidence that the aircraft is actually turning. The cross track deviation (D2) will be checked against two thresholds (TH1, TH2) which are computed from the equations shown on Table 4-5. One threshold will be small enough so that the probability of a missed alarm is small and there is little delay in detecting a turn. The other threshold will be large enough so that the probability of a false alarm or wrong alarm is minimized (see Reference 6). The transition diagram for the turn sensing states is summarized in Table 4-6.

Figure 4-13 shows the flow chart for the Z Smoothing Routine. The vertical portion of the ATARS tracker is the more customary alpha, beta tracker. ALFA, BETA values are used as selected through FIRMZ1. Let the reported altitude be ZR. At the time when smoothing occurs the altitude estimate slot in CTS holds the predicted altitude ZP1 for the current data time of a local report. For remote reports the prediction is first corrected using ZDE1 as with other predictions above. The smoothing relations are:

$$ZS1 = ZP1 + ALFA * (ZR - ZP1)$$

$$ZDE1_{next} = ZDE1 + BETA * (ZR - ZP1)/DTZ$$

where DTZ is the elapsed time since the last altitude data was measured.

$$DTZ = TM1_{NEXT} - TMZ1$$

Note that DTZ is not necessarily equal to DT. It is calculated in a similar way, however, using the last time of altitude data, TMZ1, stored in the state vector. ZS1 and $ZDE1_{next}$ are local variables and are processed further by prediction which occurs later. After smoothing set TMZ1 = $TM1_{next}$.

In the case that the report is a radar fill-in or for other reasons the altitude measurement is not usable,

$$ZS1 = ZP1$$

$$ZDE1_{next} = ZDE1$$

TABLE 4-4

TURN SENSING STATES

TURN 1 (STATE)	DEFINITION
-2	We are very confident that the aircraft is turning left.
-1	We are slightly confident that the aircraft is turning left.
0	We are very confident that the aircraft is going straight.
+1	We are slightly confident that the aircraft is turning right.
+2	We are very confident that the aircraft is turning right.
-3	We are uncertain about the aircraft's turn status.
+3	We are uncertain about the aircraft's turn status.

TABLE 4-5

EQUATIONS FOR TURN SENSING

$$C2T = \frac{(XA * XDA + YA * YDA)^2}{V2A * R2A}$$

$$CRNG1 = (TRKW1 * STDA + TRKW2 * SQRT\ (V2A))^2$$

$$CAZ1 = (TRKW1 * STDB + TRKW2 * SQRT\ (V2A))^2 - CRNG1$$

$$TH1 = THK * (CRNG1 + CAZ1 * C2T)$$

$$CRNG2 = (TRKS1 * STDA + TRKS2 * SQRT\ (V2A))^2$$

$$CAZ2 = (TRKS1 * STDB + TRKS2 * SQRT\ (V2A))^2 - CRNG2$$

$$TH2 = THK * (CRNG2 + CAZ2 * CZT)$$

TABLE 4-6

TRANSITION DIAGRAM FOR TURN SENSING

STATE (TURN)	STRONG LEFT (IHIT=-2)	WEAK LEFT (IHIT=-1)	STRAIGHT (IHIT=0)	WEAK RIGHT (IHIT=+1)	STRONG RIGHT (IHIT=+2)
-2	-2	-1	0	+3	+3
-1	-2	-1	0	+3	+3
0	-1	-1	0	+1	+1
+1	-3	-3	0	+1	+2
+2	-3	-3	0	+1	+2
-3	-1	-1	0	+3	+3
+3	-3	-3	0	+1	+1

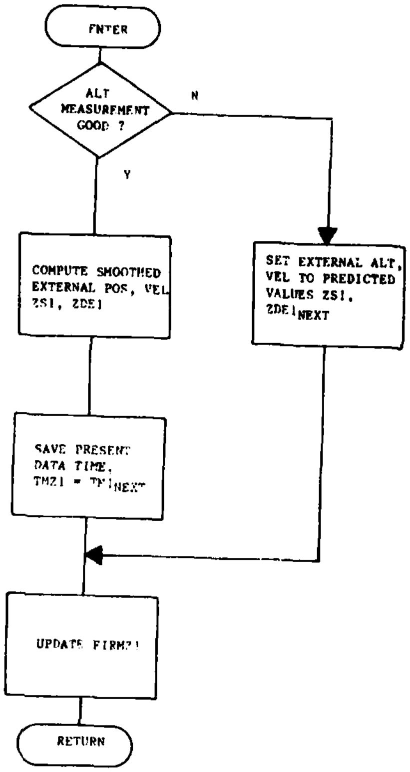


FIGURE 4-13
Z SMOOTHING ROUTINE

4.6.2 Prediction

When a track receives data, prediction is done just after smoothing. The various smoothed estimates are projected ahead to the next local correlation time using the appropriate smoothed velocities. The velocities are not modified. When a track receives no data, the previous predictions are treated as if they were new smoothed estimates and are predicted again. In this case, prediction is accomplished during first pass processing in the tracking module.

Figure 4-14 shows the flow chart for the X, Y, Z Prediction Routine.

Let DS be the estimated time to the next local report. Then,

$$XDI1 = XDI1_{next}$$
$$YDI1 = YDI1_{next}$$

$$XPI1 = XSI1 + DS * XDI1$$
$$YPI1 = YSI1 + DS * YDI1$$

$$XP1 = XS1 + DS * XDI1$$
$$YP1 = YS1 + DS * YDI1$$

To compute XPINEW, YPINEW, use time at stack top minus time at stack bottom to compute time on the stack (ST). Use position and velocity on the bottom of the stack, ST, and DS to predict the next positon.

Note that external X, Y positions are predicted using internal velocities. This is done to reduce the possible perturbations caused by false turn detections.

The vertical prediction is accomplished by computing the following:

$$ZDE1 = ZDE1_{next}$$

$$ZP1 = ZS1 + DS * ZDE1$$

In order to prepare for the next correlation, the predicted range (RHOP1) and azimuth (AZP1) are calculated from the external predictions and stored in the track file.

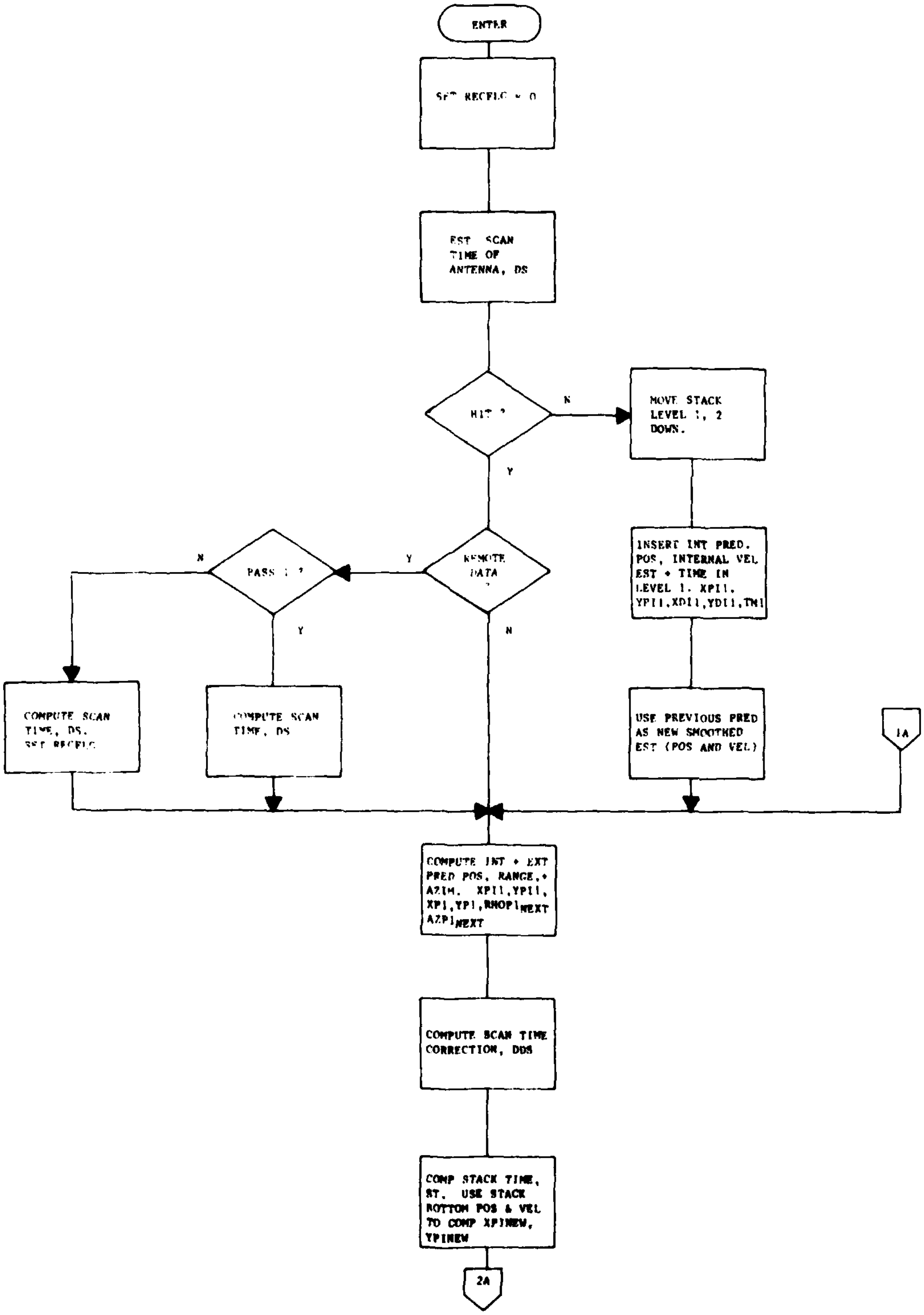


FIGURE 4-14
X, Y, Z PREDICTION ROUTINE (Page 1 of 2)

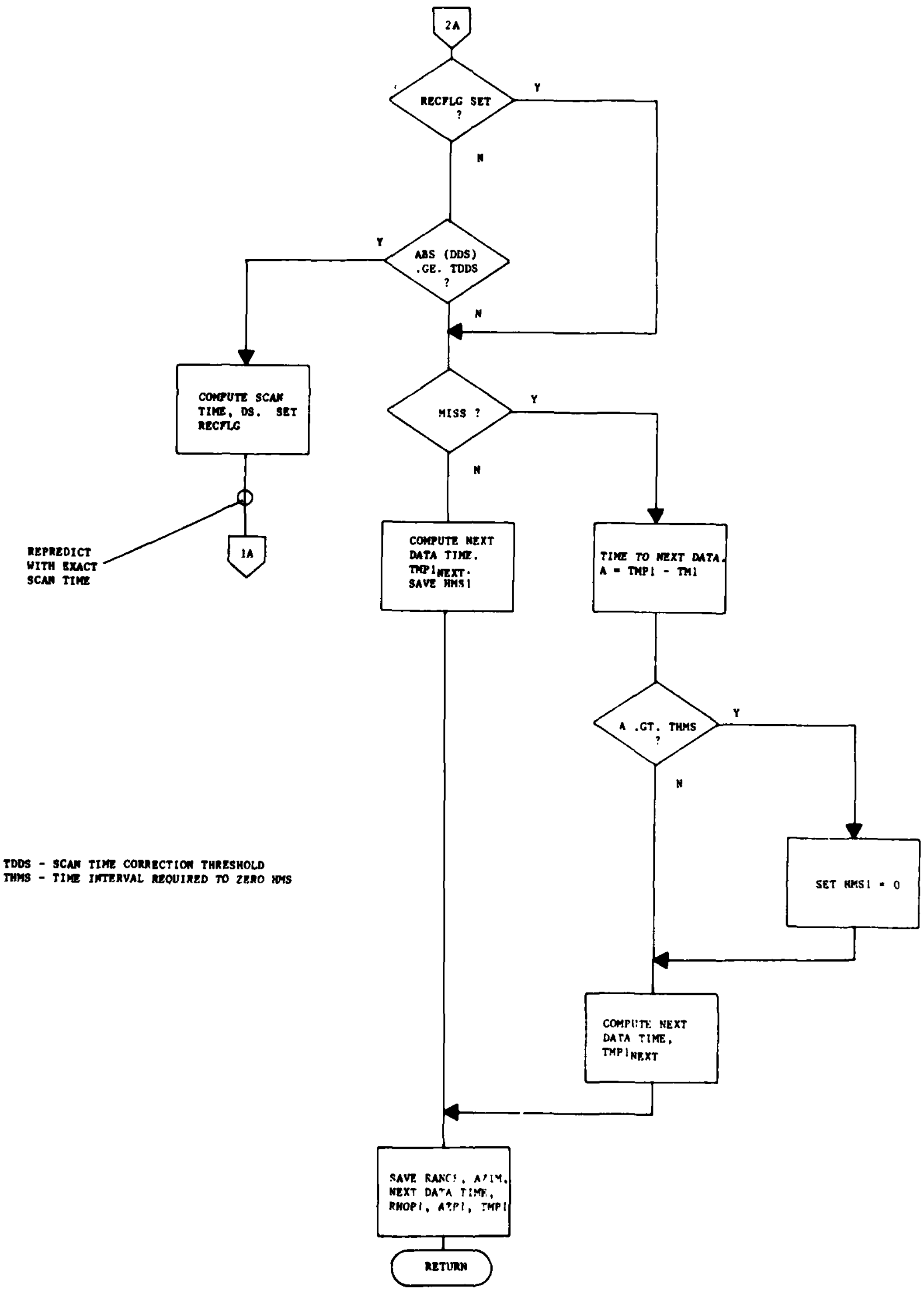


FIGURE 4-14
X, Y, Z PREDICTION ROUTINE (Page 2 of 2)

$$RHOP1_{next} = SQRT\ (XP1^2 + YP1^2 + ZP1^2)$$

$$AZP1_{next} = \tan^{-1}\ (XP1/YP1)\ \text{(with quadrant determination)}$$

For an update with local data, DS is nominally the estimated scan time of the antenna.

$$DS_{scan} = \frac{360^\circ}{ARATE}$$

The tangential motion of a track near the antenna may require a correction of this value. A method for determining whether correction is needed, is to find ($AZP1_{next}$ - AZP1) and then the increment of extra scan time which this predicted azimuth change requires. The extra time, DDS, is a correction of DS_{scan} and may be positive or negative. If the magnitude of DDS is TDDS or greater, the predictions are recalculated with the exact DS, i.e.,

$$DS = DS_{scan} + DDS$$

For an update with remote data,

$$DS = TMP1 - TMR1 + \begin{cases} DS_{scan} + DDS & \text{Pass 1} \\ 0 & \text{Pass 2} \end{cases}$$

The time for which the predictions are made, $TMP1_{next}$, is calculated and stored in the state vector.

For a hit:

$$TMP1_{next} = TMP1 + DS$$

For a miss:

$$TMP1_{next} = TMP1 + DS$$

(TM1 is the time of measurement of the current report, which replaced the old time after the call to the Z Smoothing Routine in Figure 4-8.)

4.7 Supporting Routines

This section provides a list of some common routines required by the ATARS tracker. Particular algorithms are outlined in selected cases. Track processing control flags are briefly summarized and their utility noted.

Required routines of particular importance are the following:

1. Antenna Azimuth Position/Rate Estimation

This routine is called by the Report Processing Task. The input consists of an antenna azimuth position from the header word supplied with each sector's reports in the surveillance buffer. An azimuth is received each sector, whether or not there are accompanying target reports.

It is also necessary to read the ATARS real-time clock at the time the azimuth is extracted.

The antenna estimate is embodied and stored in three variables APOS, ATIME, ARATE. Let the new input azimuth be ANAZ and the clock time CTIME. Then the estimate update is:

$$ARATE_{next} = (1 - ABETA) * ARATE + ABETA * \frac{(ANAZ - APOS)}{(CTIME - ATIME)}$$

$$APOS_{next} = ANAZ$$

$$ATIME_{next} = CTIME$$

ABETA is a smoothing constant (approx. = .5). If ANAZ - APOS is negative, add 360°. Thus this difference is always taken as a positive angle. Check CTIME - ATIME. If too small (i.e., corresponds to less than 1/2 sector) skip the update for this antenna sector.

2. Local Report Time of Measurement

The routine is used wherever local reports are utilized for track update or initialization. The input data are the measured report azimuth, AZR, and the antenna estimates.

The algorithm for measurement time, TM_{next} is:

$$TM_{next} = ATIME + \frac{(AZR - APOS)}{ARATE}$$

3. Remote Report Time of Measurement

This operation is trival and is included only for contrast with the item above. Remote report time, TMR, is computed during report processing by comparing ATARS clock time with the report storage delay, TDELA, provided with the report.

TMR = TCLOCK - TDELA

4. Coordinate Conversions

a. Local rho, theta to X, Y.
b. Local X, Y to rho, theta.
c. Remote rho, theta to local X, Y.

See Section 4.2 and Figure 4-1 for a brief general description of the coordinate framework.

Note that remote sensor site parameters must be stored and used in c in the above list. A selection of parameters is made through the sensor ID supplied with each report.

5. Sector Thread Update

The requirements of this program (or programs) are to:

a. add a new track to a sector thread,
b. delete a track from a sector thread,
c. change a track from one sector thread to another.

6. DABS Cross-Reference (CREFD) Update

The requirements of this routine are to create or delete a CREFD link to a track.

7. CREFA Reference

This routine locates a given track in CTS from its ATCRBS file number by utilizing CREFA. Or it determines that no reference exists.

8. CREFD Reference

This routine provides a function similar to 7., but for a DABS ID using CREFD.

The following is a brief summary of required CTS state vector processing flags and indicators used in the Track and Report Processing Tasks. Their operation and function in the program are outlined.

1. LOFL: local data flag
   RMFL: remote data flag

   These flags indicate the source type of a report stored with a track in CTS. They are set when the report is stored and cleared during track update or initialization.

   LOFL and RMFL are both used to indicate presence or absence of data from a particular site.

2. SMPR: smooth/predict flag
   SPRO: antenna sector process flag

   These flags provide internal communication and prevent confusion in the timing of operations of the tracker.

   SMPR is set when local reports are used for Track Update or Track Initialization Routine. The flag is cleared in second pass remote processing in the Track Processing Task. Its function is to inform later program tasks that an update has already occurred on this scan and to defer further updates to the next scan.

   SPRO is set after conclusion of first pass processing in the Track Processing Task. It is cleared after second pass (remote) processing. It is tested before each track is accessed in the Track Processing Task. It inhibits reprocessing a track in the second pass processing.

3. DRSUR: drop surveillance flag
   DRATS: drop ATARS service flag

   These flags indicate drop conditions. Both exist for the benefit of the State Vector Deletion Task, which takes final action when a track is to be dropped.

   DRSUR is set by the tracker when it determines that a track should be dropped (drop bit received or too much time elapsed since last data input).

   DRATS is set when the Track Update Routine determines that the track is not qualified for ATARS service or is outside the service area. Otherwise, it is cleared during update.

4. ATSS: ATARS service flag

This flag is set by the Track Update Routine when it determines that a track has become eligible for ATARS service. It inhibits all but the first addition of a track to the XINIT list. The flag is cleared by the State Vector Deletion Task when the ATARS service is discontinued (in response to a DRATS indication or because the geography checks shows the tracks to be outside the service area).

Three operations require coordinated actions between the Track Processing Task and subsequent ATARS tasks. These are to:

1. start ATARS service for a track,

2. drop ATARS service for a track,

3. drop surveillance for a track.

A surveillance drop is a total drop from the track and cross-reference files. But, an ATARS service drop only terminates this service; tracking is continued to be used by the Domino Routine.

These operations are coordinated by the state vector flags; ATSS, DRATS, DRSUR. Table 4-7 shows in each case the actions initiated by track processing and then the actions taken by New Aircraft Processing or State Vector Deletion Tasks to complete the operation.

It should be noted that ATARS service is discontinued when a track leaves the ATARS service area. This event is determined by Geographical Processing Routine. This routine sets the DRATS flag directly and proceeds with the final actions as indicated in the table.

TABLE 4-7

STEPS REQUIRED TO START/DROP ATARS SERVICE OR DROP SURVEILLANCE

FUNCTION	STEP I	STEP II
1. Start ATARS service	TRACK PROCESSING TASK Set ATSS flag. Put track in XINIT list. Reset DRATS.	NEW AIRCRAFT PROCESSING TASK Remove from XINIT list. Put in appropriate X list. Set INXFL. Initialize State Vector.
2. Drop ATARS service	TRACK PROCESSING TASK Set DRATS flag. Reset ATSS.	
3. Drop ATARS/ domino surveillance	TRACK PROCESSING TASK Set DRSUR flag OR REPORT PROCESSING TASK Set DRSUR flag OR GEOGRAPHICAL PROCESSING ROUTINE Reset ATSS Set DRATS	STATE VECTOR DELETION TASK Remove track from appropriate X list. Remove from sector list and add to empties* Erase CREFD link.

* This action effectively erases the track from CTS.

5. NON-SURVEILLANCE PROCESSING

All of the non-surveillance data passed between ATARS and the DABS sensor is also processed on an antenna sector basis. Some of this data is passed through the Non-surveillance Buffer. The formats of these messages, which apply only to DABS aircraft, are presented in Table 5-1. Certain messages are processed once per sector at the initiation of report processing. Other messages are processed by later routines, as described below. The rest of the data is passed through the CIR Buffer and reflects the CIR contents for each DABS aircraft.

5.1 Incoming Messages

5.1.1 Uplink Delivery Notice Processing

ATARS uplink messages for an individual DABS aircraft are delivered to the Uplink Message Buffer as an ordered set. The UPMES pointer in the aircraft state vector contains the location in memory of this set of messages (UPLST). The position of each message within the set corresponds to its intended position in the desired uplink sequence. The ACMES pointer contains the location in memory of the set of messages (ACLST) which was successfully delivered on the previous scan. The DABS sensor returns an uplink delivery notice for each message indicating its success or failure in delivery. All notices for an aircraft are delivered in one contiguous block, but not necessarily in the order of uplink. For this reason, delivery notices are numbered to correspond to the intended order of uplink.

When the set of uplink delivery notices for each aircraft is processed, the message number field in each notice is matched with a message in the set identified by UPMES. Figure 5-1 presents these two data structures. Figure 5-2 presents the flow chart for processing delivery notices. The new ACLST is built only using messages which were successfully delivered. A local flag (ALLUP) is used to indicate whether all uplinks were successful. If so, the UPMES pointer is set equal to ACMES and the (duplicate) UPLST space can be immediately released. Otherwise, both UPLST and ACLST are saved so that other tasks may test the success of individual messages by comparing these lists.

5.1.2 Data Link Capability Message

When a Data Link Capability Message is received, the value of ATSEQ in the state vector is set to indicate whether or not the

TABLE 5-1

CONTENT OF MESSAGES IN NON-SURVEILLANCE BUFFER

SENSOR-TO-ATARS:	ATARS-TO-SENSOR:
__Uplink Delivery Notice__	__Start/Stop ATARS Service__
Type code	Type Code
DABS ID	DABS ID
Message no.	ATARS Site ID (local or remote)
Successful delivery flag	Start/Stop flag
__Data Link Capability__	__BCAS Squitter Lockout__
Type code	Type code
DABS ID	DABS ID
Capability field value	Start/Stop flag
__Sensor Failure/Recovery__	__Set BCAS PLC__
Type Code	Type Code
Site ID	DABS ID
Sensor Status	PLC field
	__Data Link Capability Request__
	Type Code
	DABS ID

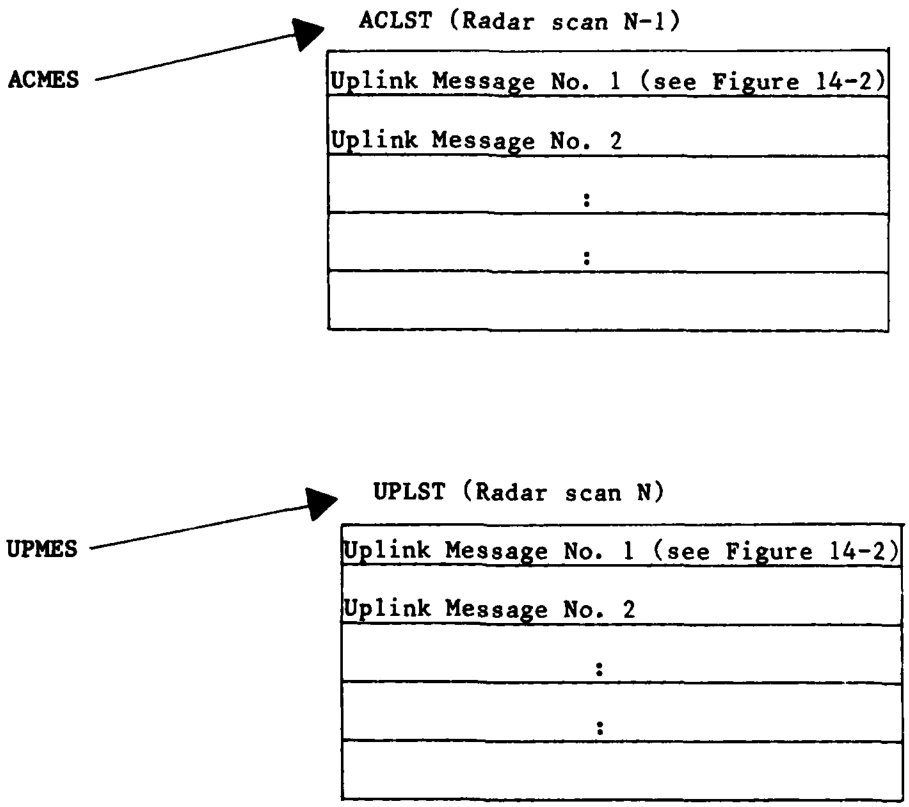


FIGURE 5-1
UPMES/ACMES POINTER AND UPLINK MESSAGE DATA STRUCTURE

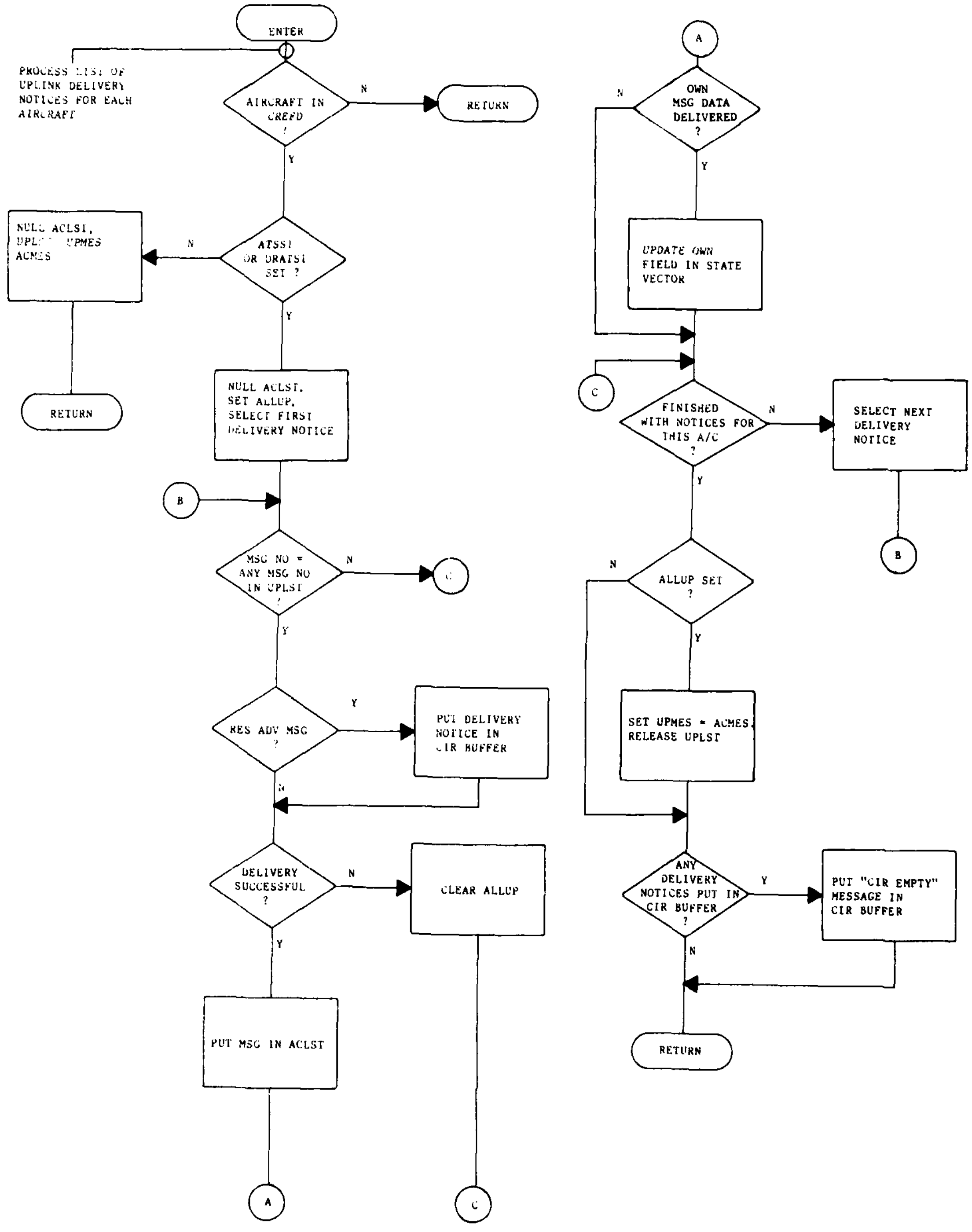


FIGURE 5-2
UPLINK DELIVERY NOTICE PROCESSING ROUTINE

aircraft is equipped with ATARS or BCAS. If the aircraft is not equipped with ATARS, it will be considered unequipped and receive no direct ATARS service.

The detailed flow chart of the Data Link Capability Message Processing Routine is presented in Figure 5-3.

5.1.3 Sensor Failure/Recovery

The ATARS function will be informed of the failure of an adjacent site by the Sensor Failure/Recovery Message. The ATARS function will use the Site ID Field to initiate the failure mode operation logic (see Section 15).

5.2 Outgoing Messages

5.2.1 Start/Stop ATARS Service

When an aircraft has entered the ATARS service area, a start ATARS service message will be sent to the DABS sensor. The sensor will then begin to uplink the ATARS site ID each scan and downlink the CIR rows for the indicated DABS aircraft. The start message is generated in the Track Update Routine. A stop ATARS service message is sent to the sensor when the aircraft leaves the ATARS service area, or when the track is lost. This message is generated in the Geographical Processing Routine or in the Track Update Routine, for the case of a lost track.

5.2.2 BCAS Squitter Lockout

When an aircraft which is BCAS equipped penetrates the ATARS service area beyond a designated ATARS-BCAS seam, the BCAS Squitter Lockout Message is sent to the DABS sensor. The sensor surveillance uplink will then inhibit BCAS interrogations while the aircraft is inside this ATARS-only area. When an aircraft leaves this area, an end message is sent to the DABS sensor. These messages are implemented in the Geographical Processing Routine (Section 6.3).

5.2.3 Set BCAS Performance Level Control (PLC)

When a BCAS aircraft enters the ATARS service area, ATARS will generate a message to select desensitized BCAS logic thresholds. ATARS uses a site-specific area map to determine the applicable zone boundaries. This function is controlled by the Geographical Processing Routine. Its purpose is to allow ATARS to be the primary collision avoidance system in the ATARS service area.

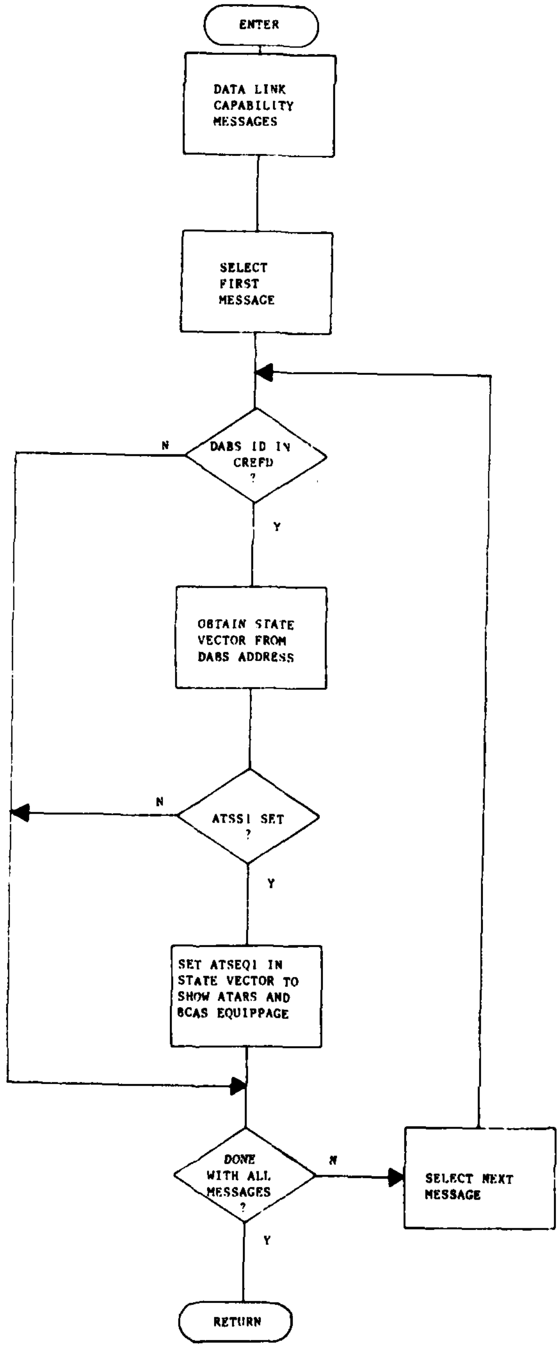


FIGURE 5-3
DATA LINK CAPABILITY MESSAGE PROCESSING ROUTINE

5.3 Conflict Indicator Register Processing

The Conflict Indicator Register (CIR) Processing Task is performed after CIR rows and uplink messages from the local site have been exchanged with a CIR-equipped aircraft. The purpose of this task is to update the ATARS conflict data and to determine the acceptance of the resolution advisories and handoff messages uplinked by the local site. In addition, for conflicts involving a controlled aircraft, the Controller Alert List is updated. CIR data is passed from DABS to ATARS in the CIR Buffer. Table 5-2 indicates the contents of the CIR Buffer.

Figure 5-4 gives the flow chart for the CIR Processing Task. In the event that all CIR rows and uplinked resolution advisories are not successfully exchanged with an aircraft during the antenna beam dwell, no CIR processing takes place for the aircraft on that scan except for the processing of the site ID bits, if they were successfully received.

The downlinked CIRs for the current sector are processed one at a time. The first step in this processing is to send the contents of the CIR to any remote ATARS site which has requested this data. This is done in the CIR Remote Processing Routine, which is shown in Figure 5-5. When this requirement is dropped, the Stop Remote CIR Data Routine, described in Section 12.3, is called.

The CIR Processing Task next tests to see if the local site is providing ATARS service, or extended service, to the subject aircraft. Extended service implies that the aircraft has flown out of the regular service area, but that CIR communications will continue until all required handoff messages have been successfully uplinked by the local site. This condition is indicated when the DRATS1 flag is set. If service is being provided by the local site, the CIR site ID bits are saved in the GEOG1 variable and processing continues.

The CIR Threat Correlation Routine is executed next. This routine identifies each threat indicated in a CIR row and replaces the threat ID (and ATCRBS track block) with a pointer to an ATARS state vector or remote list entry. The CIR Threat Correlation Routine is described more fully in Section 5.3.1.

Next, a series of routines are executed to update the ATARS conflict data for the subject aircraft. This job is broken up according to system responsibility for each conflict. "Internal" conflict pairs are defined to be those pairs for which the local

TABLE 5-2

CONTENTS OF THE CIR BUFFER

The CIR Buffer will contain the following data for each CIR-equipped aircraft in the current sector for which a successful downlink of the CIR was achieved:

1. Header, consisting of:

Site ID Bits	-	A 4-bit field indicating which ATARS sites are currently providing service to the subject aircraft.
ACID	-	DABS ID of the subject aircraft.

2. CIR Rows (variable number; or null if none) which may be of *two different types:*

(A) Maneuver Intent Row, consisting of:

TYPE	-	Threat type (DABS or ATCRBS).
D	-	Resolution advisory field.*
VSL	-	Vertical speed limit field,* considered to be part of the resolution advisory.
RRS	-	Resolution responsibility field,* indicating BCAS responsibility (B-bit set), ATARS responsibility (C-bit set, plus row ID), or a handoff condition.
TRTID	-	ID of threat aircraft: If TYPE = DABS, TRTID = DABS ID. If TYPE = ATCRBS, TRTID consists of: AIA - ATCRBS ID availability flag. AID - ATCRBS ID code (= 0 when AIA is not set).

* Coding of these fields is described in Reference 5.

TABLE 5-2

CONTENTS OF THE CIR BUFFER
(Concluded)

(B) ATCRBS Track Block Row*, consisting of:

R	-	Range of threat.
RD	-	Range rate of threat.
THETA	-	Bearing of threat.
THDOT	-	Bearing rate of threat.
Z	-	Mode-C altitude of threat.
ZD	-	Altitude rate of threat.

3. Uplink delivery notices, used to determine whether all resolution advisories were successfully delivered by the local site.

---

* An ATCRBS track block row immediately follows a maneuver intent row where TYPE = ATCRBS.

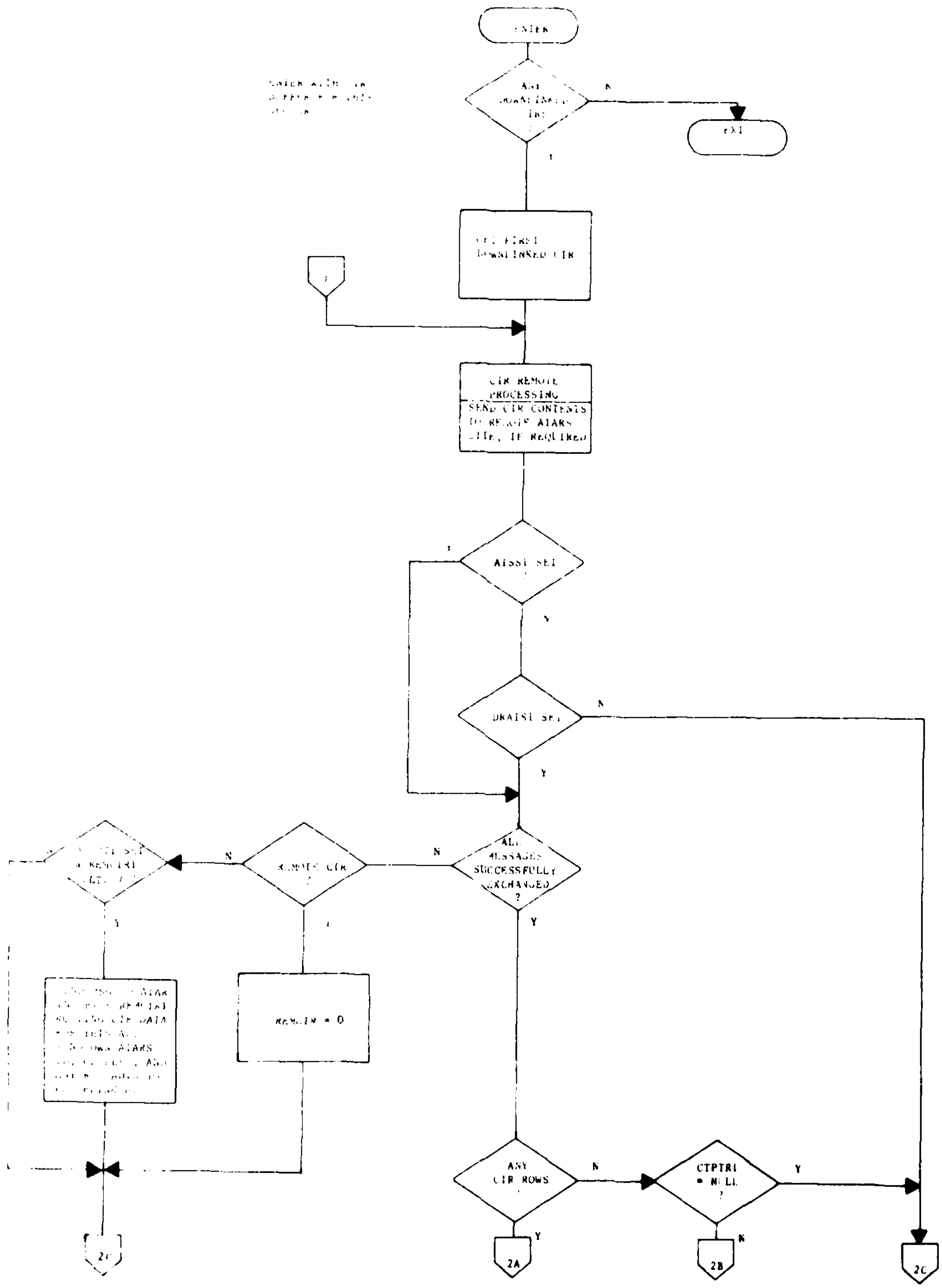


FIGURE 5-4
CIR PROCESSING TASK (PAGE 1 OF 2)

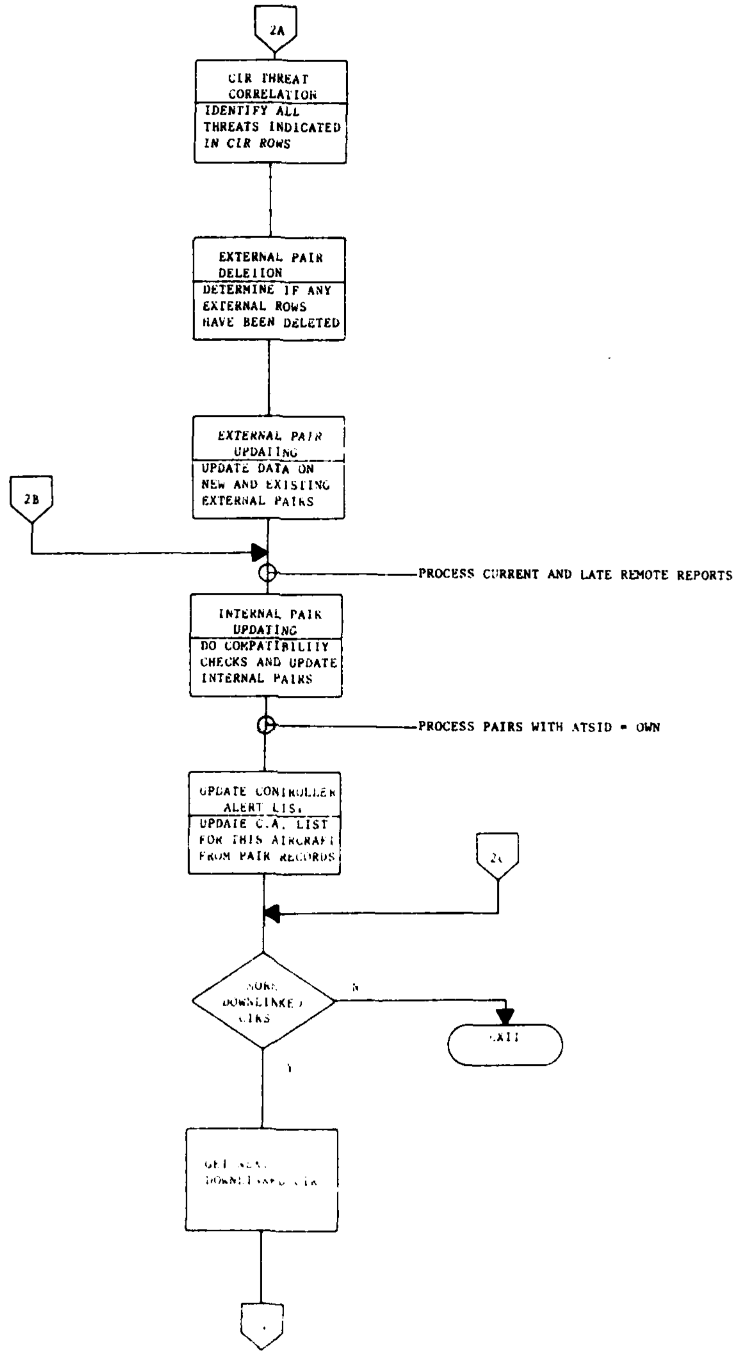


FIGURE 5-4
CIR PROCESSING TASK (PAGE 2 OF 2)

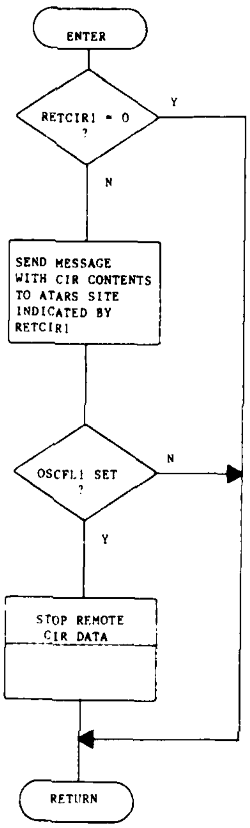


FIGURE 5-5
CIR REMOTE PROCESSING ROUTINE

ATARS site has chosen, or will choose, resolution advisories. These are identified by pair records with POSCMD less than zero or a SEND flag (SEND1 or SEND2) which is set. All other pairs are "external" pairs, and they include conflicts where resolution responsibility belongs to BCAS or another ATARS site.

The External Pair Deletion Routine is executed first. This routine searches the existing pair records to determine if any external CIR rows have been deleted. The routine is more fully described in Section 5.3.2. Next is executed the External Pair Updating Routine, which updates the ATARS conflict data for new and existing external pairs. This routine is described in detail in Section 5.3.3. Finally, the Internal Pair Updating Routine is called to determine the compatibility of uplinked resolution advisories with existing CIR rows. The acceptance of null resolution advisories and handoff messages is also noted and recorded. The Internal Pair Updating Routine is described in Section 5.3.4.

The last step in the CIR Processing Task is to update the Controller Alert List for the subject aircraft to reflect the resolution advisories actually in effect. This information is extracted from the updated pair records involving the subject aircraft. Note that the controller is informed of each resolution advisory generated by the local site only after it has been accepted by the aircraft. The Update Controller Alert List Routine is fully described in Section 11.

5.3.1 CIR Threat Correlation

The CIR Threat Correlation Routine is flow charted in Figure 5-6. Its purpose is to identify each threat by associating it with an ATARS state vector or remote list entry. Correlation takes place for one CIR row at a time.

For each DABS threat, the DABS ID code is used to determine whether an ATARS state vector or remote list entry currently exists for the threat. If not, a new REMD entry is created. The DABS ID in the CIR row is then replaced with a pointer to the state vector or remote list entry.

For each ATCRBS threat, the CIR ATCRBS Correlation Routine is first executed. This routine, shown in Figure 5-7, attempts to correlate the threat with an existing state vector or REMA entry. It is intended that the positional correlation logic in this routine will match the corresponding avionics logic, described in the BCAS collision avoidance algorithms (see Reference 5), as

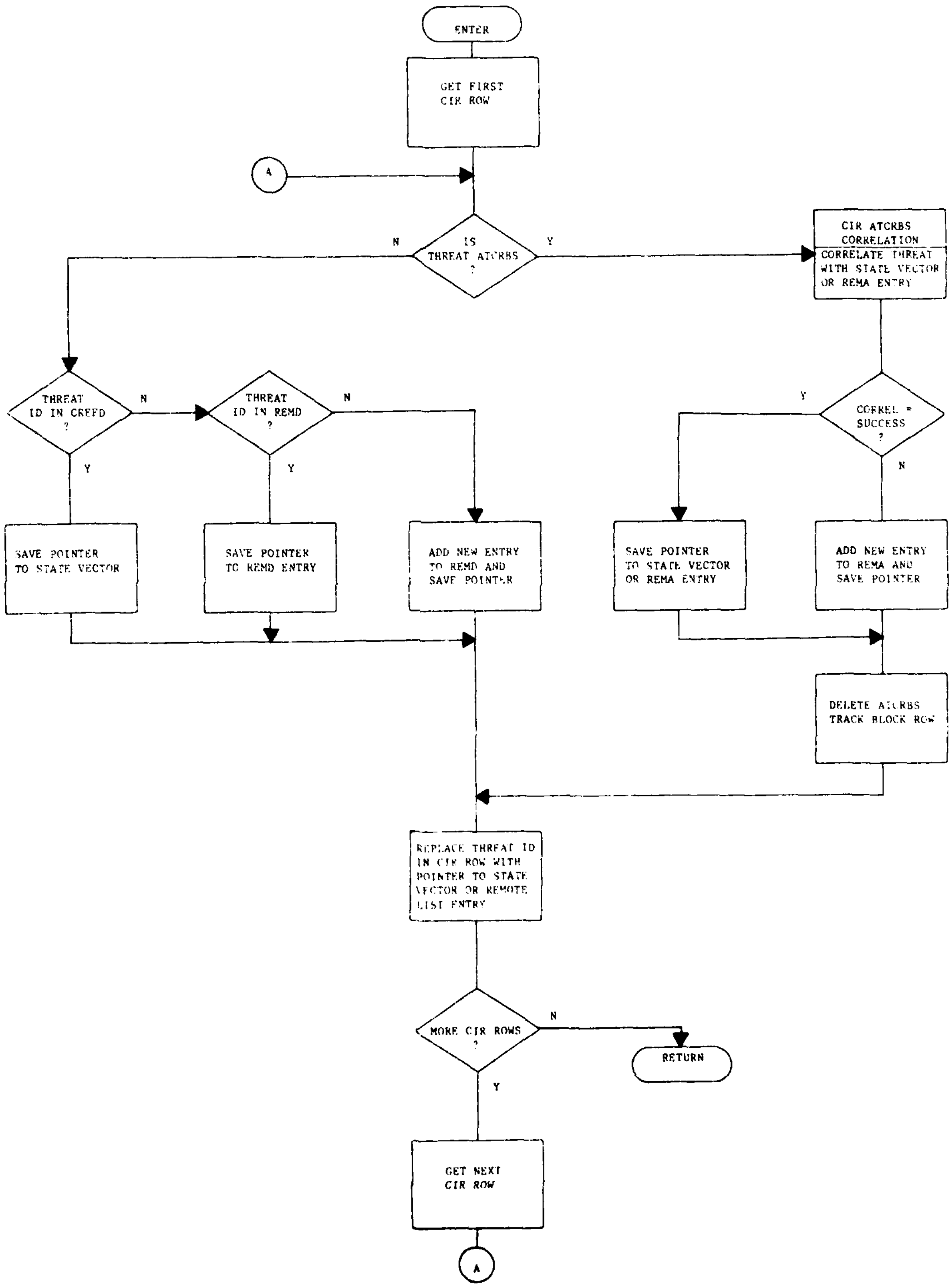
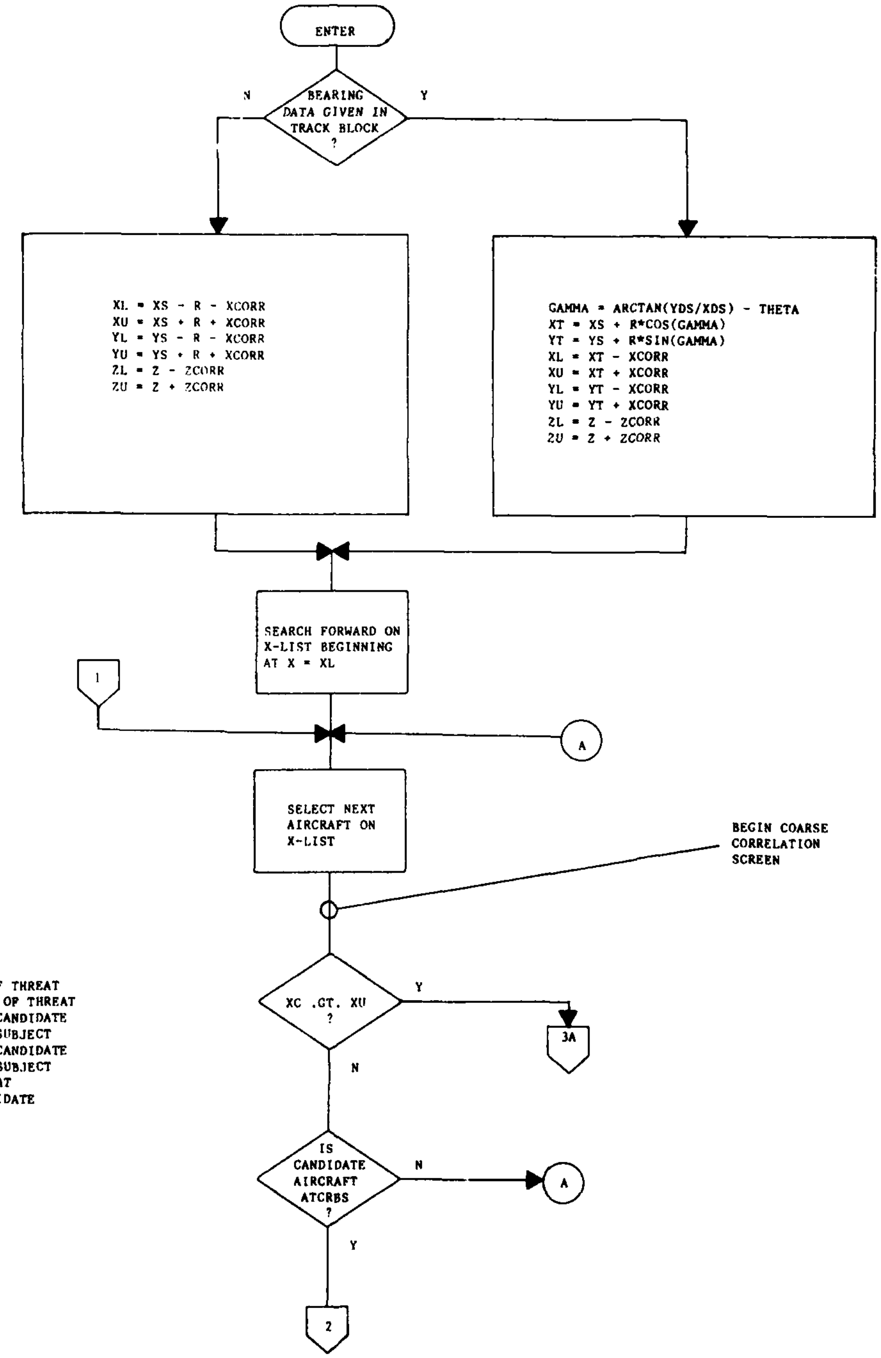


FIGURE 5-6
CIR THREAT CORRELATION ROUTINE

ENTER WITH CIR
MANEUVER INTENT
AND TRACK BLOCK
ROWS FOR ATCRBS
THREAT



DEFINITIONS:

R	= RELATIVE RANGE OF THREAT
THETA	= RELATIVE BEARING OF THREAT
XC	= X-COORDINATE OF CANDIDATE
XS	= X-COORDINATE OF SUBJECT
YC	= Y-COORDINATE OF CANDIDATE
YS	= Y-COORDINATE OF SUBJECT
Z	= ALTITUDE OF THREAT
ZC	= ALTITUDE OF CANDIDATE

FIGURE 5-7
CIR ATCRBS CORRELATION ROUTINE (Page 1 of 6)

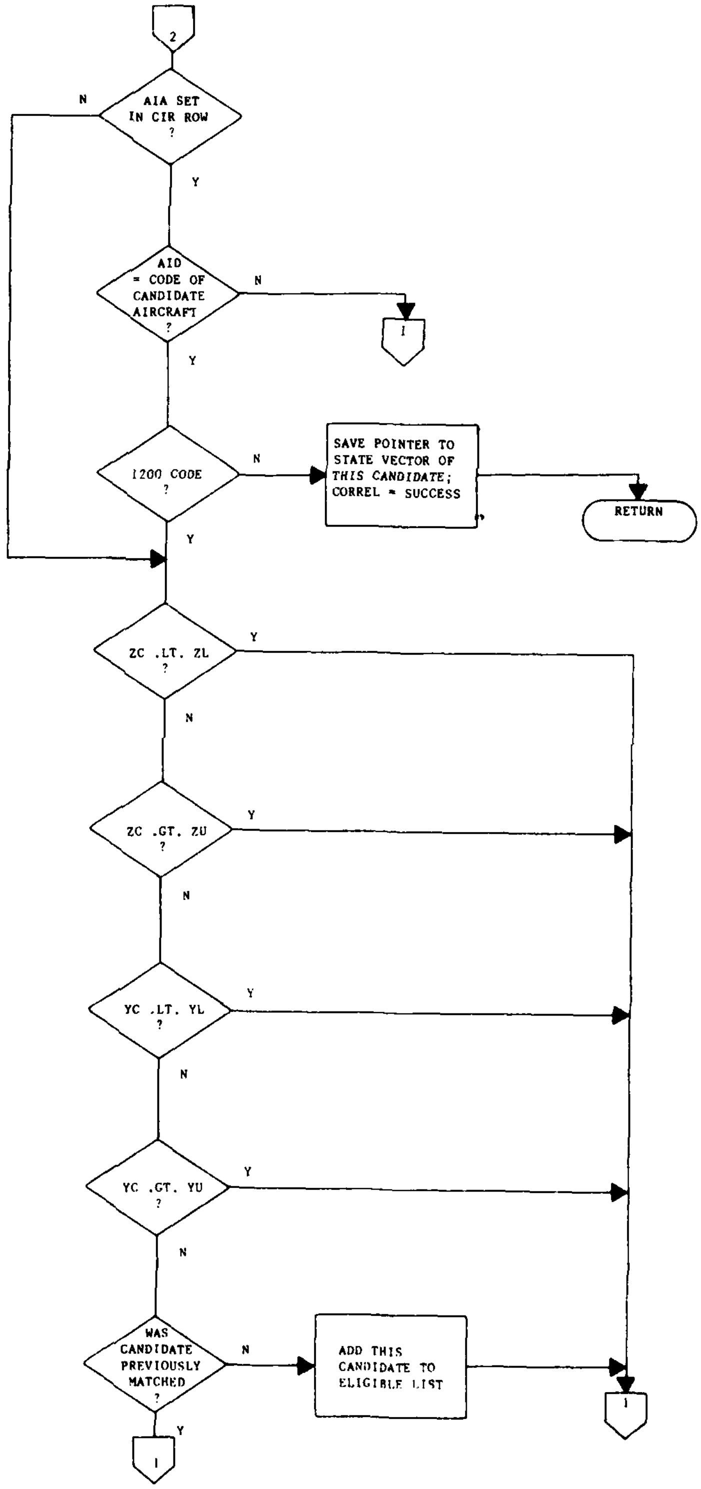
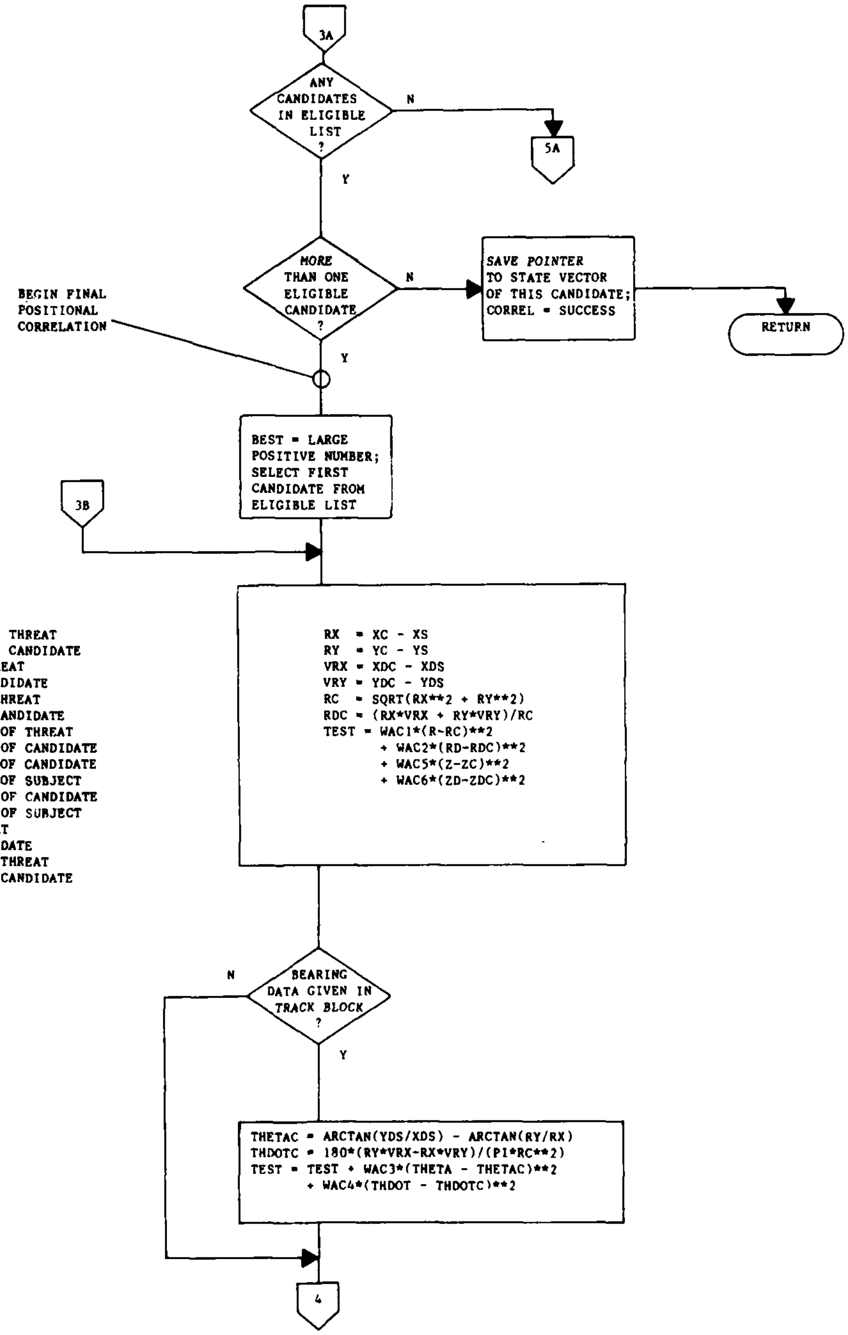


FIGURE 5-7
CIR ATCRBS CORRELATION ROUTINE (Page 2 of 6)



DEFINITIONS:

R	= RELATIVE RANGE OF THREAT
RC	= RELATIVE RANGE OF CANDIDATE
RD	= RANGE RATE OF THREAT
RDC	= RANGE RATE OF CANDIDATE
THDOT	= BEARING RATE OF THREAT
THDOTC	= BEARING RATE OF CANDIDATE
THETA	= RELATIVE BEARING OF THREAT
THETAC	= RELATIVE BEARING OF CANDIDATE
XDC	= X-VELOCITY COMP. OF CANDIDATE
XDS	= X-VELOCITY COMP. OF SUBJECT
YDC	= Y-VELOCITY COMP. OF CANDIDATE
YDS	= Y-VELOCITY COMP. OF SUBJECT
Z	= ALTITUDE OF THREAT
ZC	= ALTITUDE OF CANDIDATE
ZD	= ALTITUDE RATE OF THREAT
ZDC	= ALTITUDE RATE OF CANDIDATE

FIGURE 5-7
CIR ATCRBS CORRELATION ROUTINE (Page 3 of 8)

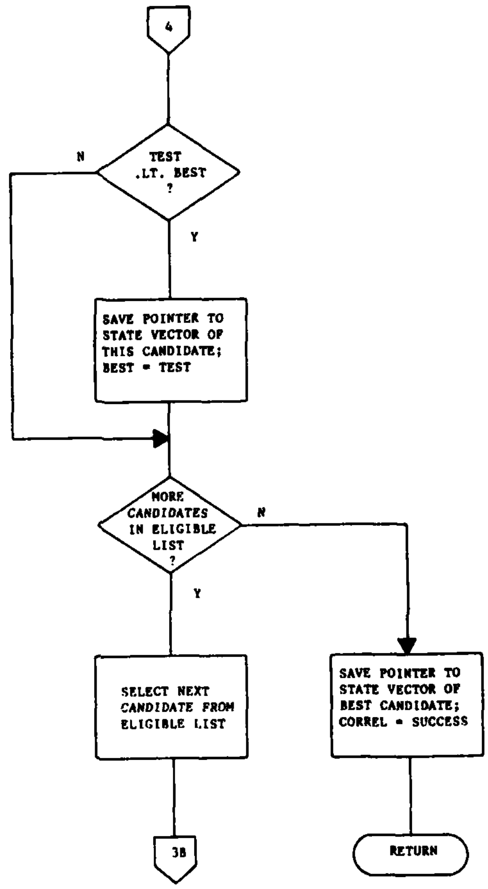


FIGURE 5-7
CIR ATCRBS CORRELATION ROUTINE (Page 4 of 6)

ATTEMPT TO
CORRELATE WITH
EXISTING THREATS
ON REMOTE LIST

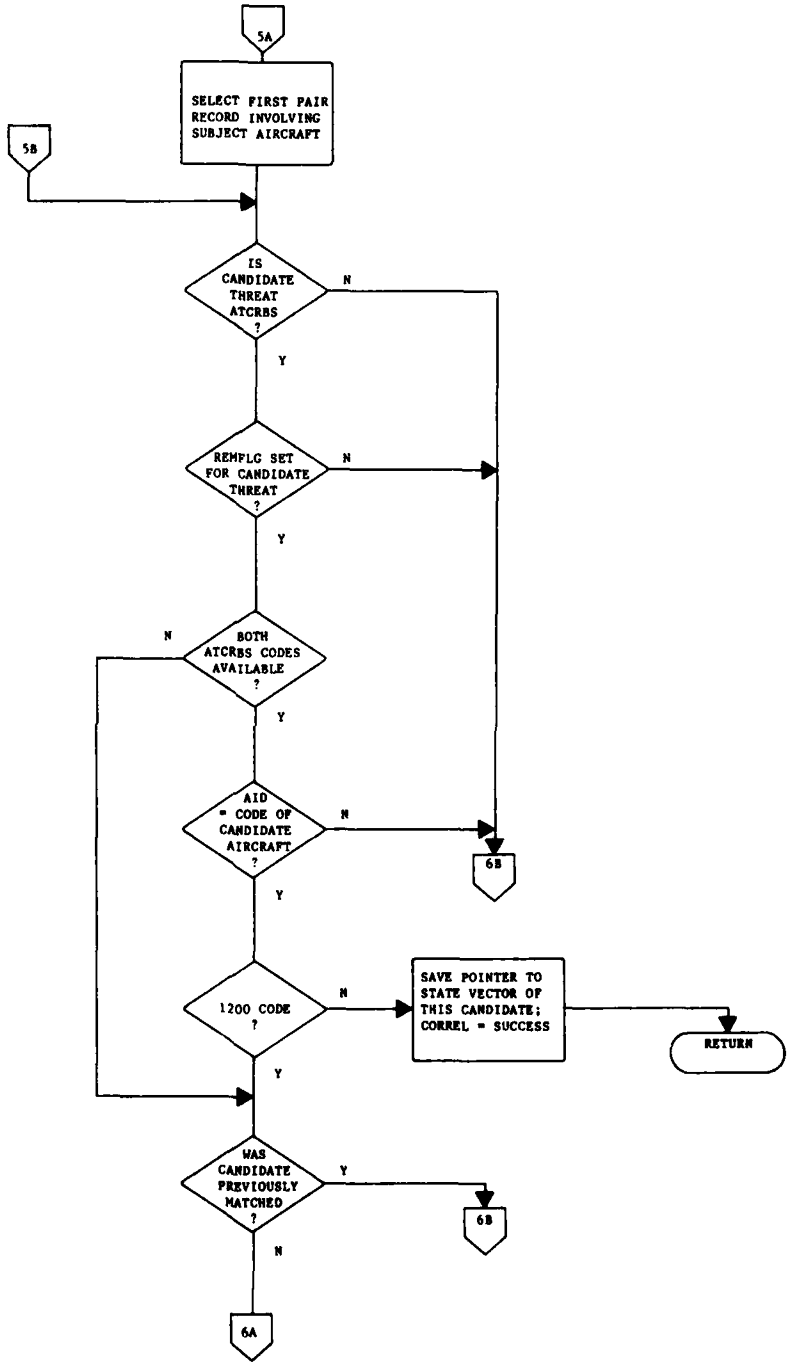


FIGURE 5-7
CIR ATCRBS CORRELATION ROUTINE (Page 5 of 6)

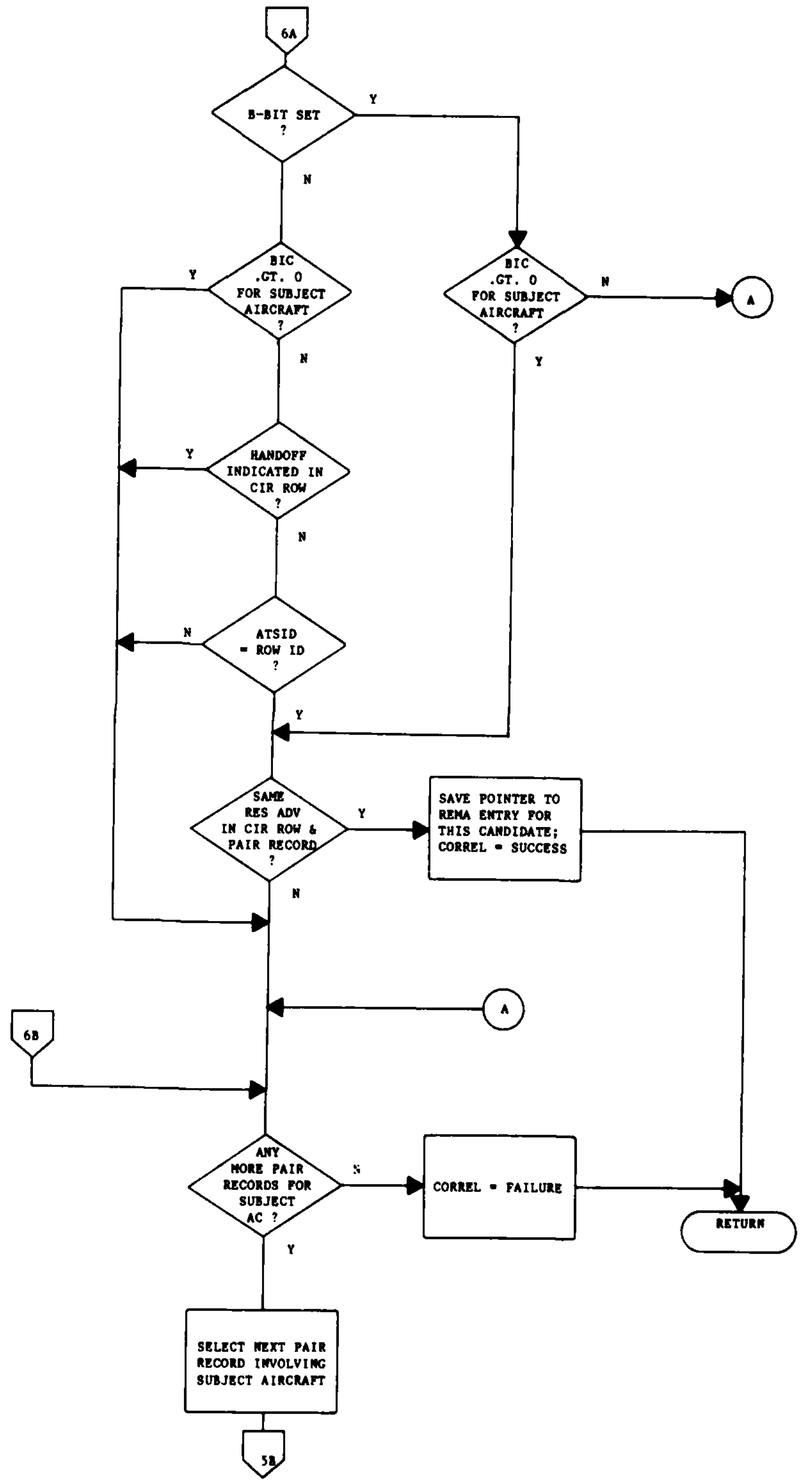


FIGURE 5-7
CIR ATCRBS CORRELATION ROUTINE (Page 6 of 6)

closely as possible. An attempt is first made to correlate the threat with an existing state vector by matching the ATCRBS ID code (if available). A matching non-1200 code is considered an immediate correlation success. If the ID code check is inconclusive, a coarse correlation screen of positional data is performed using the current X-list. The result is a list of eligible candidates to be used for final positional correlation. One candidate is chosen from the list whose current positional data best matches that in the ATCRBS track block in the least-squares sense.

If the list of eligible candidates from the coarse positional correlation proves to be empty, an attempt is next made to match the threat with existing REMA entries for any threats for which a pair record already exists. Again, an attempt is first made to match the ATCRBS ID code. If this is inconclusive, the logic tries to match the system responsible (using BIC and ATSID) and the resolution advisory. It should be pointed out that the correlation of remote threats is attempted primarily as a matter of efficiency, and success is not critical.

If the CIR ATCRBS Correlation Routine was not successful, a new REMA entry is created for the threat. Finally, the ATCRBS track block row is deleted and the threat ID is replaced with a pointer to the state vector or REMA entry of the threat aircraft.

5.3.2 External Pair Deletion

In the External Pair Deletion Routine, the existing pair records involving the subject aircraft are searched for external conflicts for which there are no corresponding CIR rows. Such pair records are deleted whenever possible; otherwise, the absence of a resolution advisory for the subject aircraft is recorded in the conflict table. Figure 5-8 gives the flow chart of the External Pair Deletion Routine.

In general, a pair record can be deleted when no resolution advisory is recorded for either aircraft and the local site is not attempting to uplink a null resolution advisory (i.e., neither SEND flag is set). The Pair Record Deletion Routine is described in Section 13.2. Conflicts resolved by BCAS are handled in a special manner. Instead of deleting the pair record as soon as the resolution advisories have disappeared, the BIC variable is used to maintain the pair record until resolution advisories have been absent for BDROP successive scans. This feature ensures that ATARS will not "jump in" because of surveillance differences or tracker lag and uplink final resolution advisories for a conflict which BCAS has already resolved.

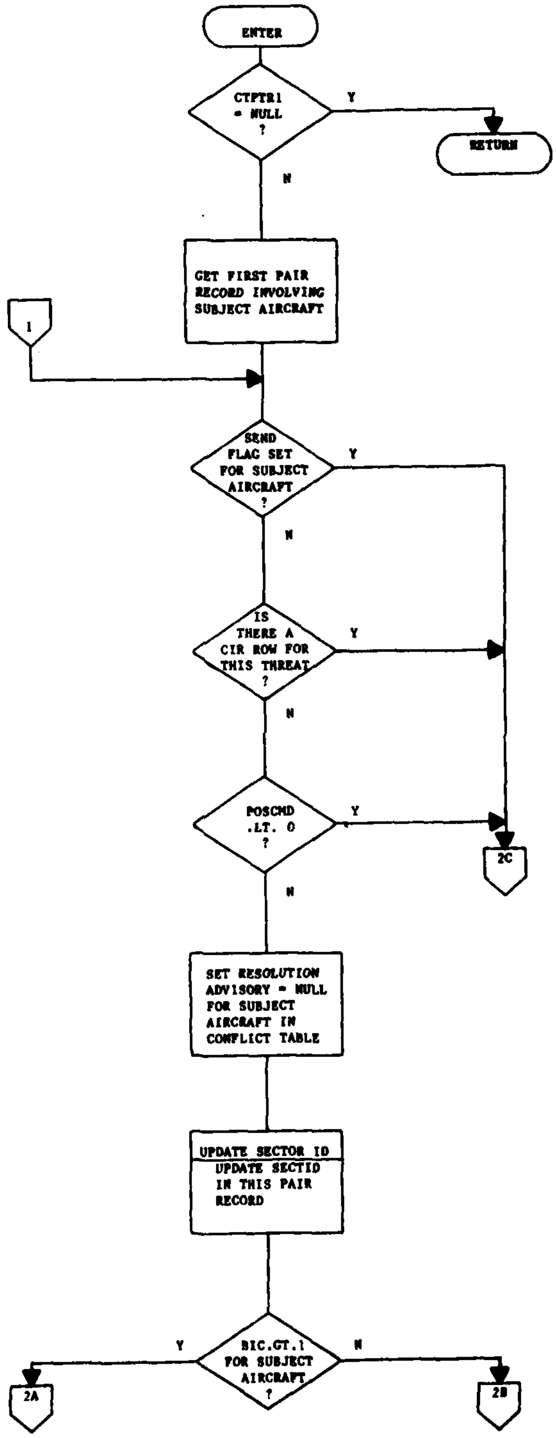


FIGURE 5-6
EXTERNAL PAIR DELETION ROUTINE (Page 1 of 2)

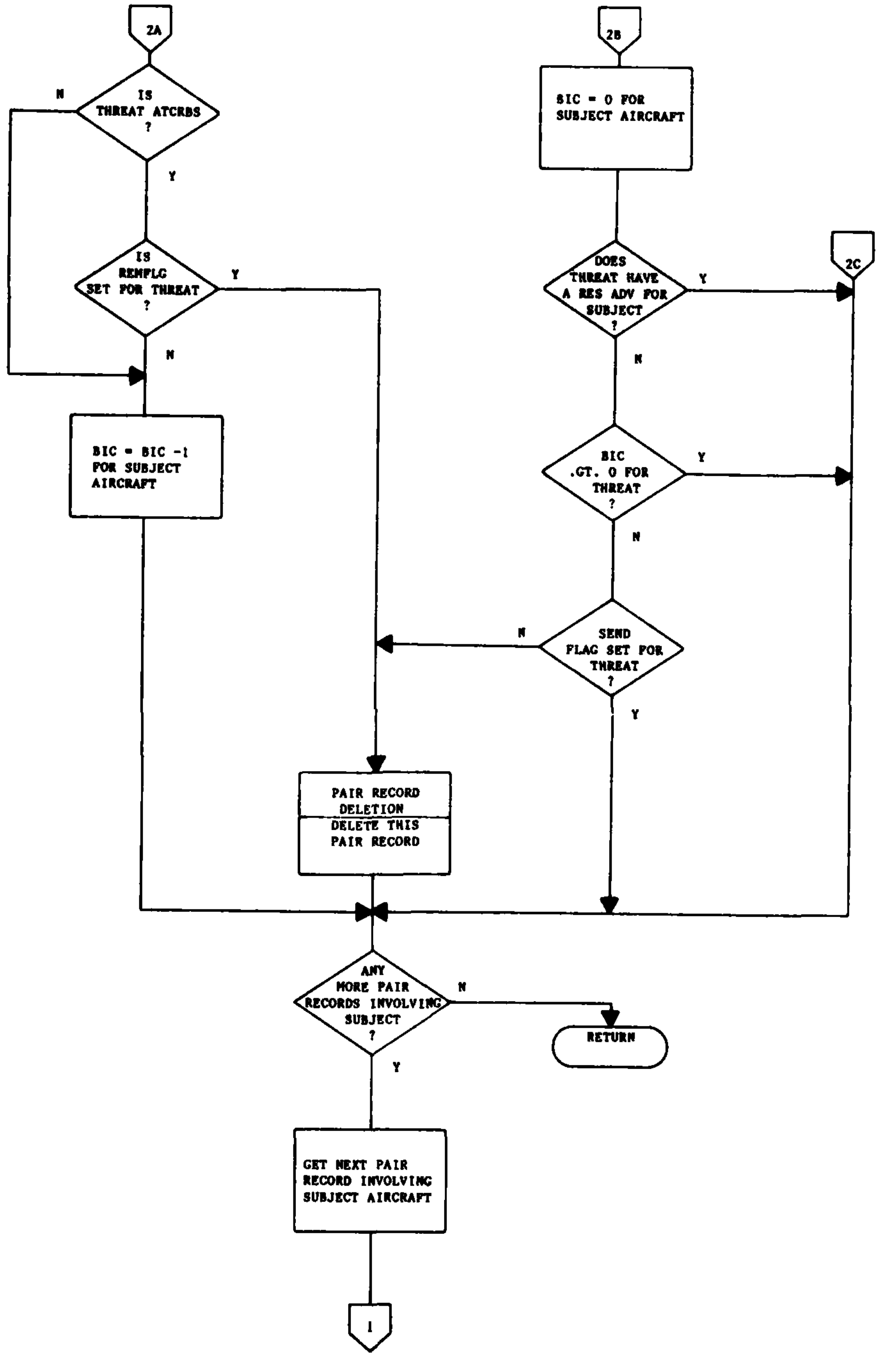


FIGURE 5-8
EXTERNAL PAIR DELETION ROUTINE (Page 2 of 2)

For external pair records which are not deleted, the sector ID must be updated. This is done by the Update Sector ID Routine, described in Section 5.3.5. Also, it should be pointed out here that whenever a resolution advisory field is initialized, changed, or erased in a pair record, the appropriate intermediate maneuver table and conflict table entries must also be updated. (These data structures are described in Section 9.1).

5.3.3 External Pair Updating

The External Pair Updating Routine is given in Figure 5-9. The purposes of this routine are to update the ATARS conflict data for existing external pairs and to create new pair records for external conflict pairs discovered for the first time on this downlink. If the row ID for a new external pair matches the local site ID, the "external" bit is set in ATSID to distinguish this pair from those being resolved by the local site. (This is important for the backup mode of operation.) If a new conflict table entry is created for a threat, the ACID field in the conflict table entry is initialized to point to the state vector or remote list entry of the threat. If the threat is remote, REMFLG is set and CTE and CTPTR are initialized in the remote list entry. Also, see the programming notes in Section 9.7 pertaining to the creation of pair records.

The pair record sector ID for new and existing external pairs is updated by the Update Sector ID Routine (described in Section 5.3.5). This is followed by the updating of the "system responsible" data (BIC and ATSID). Next, the resolution advisory for the subject aircraft is updated in the conflict table, and the POSCMD and TSTART variables are set. A value of 0 for TSTART implies a value less than any actual clock value to which TSTART might be compared. It should be noted that the internal ATARS representations of resolution advisories are different than those used in the CIR format. Therefore, a translation is implied when comparing or copying advisories between a conflict table and a CIR row. Table 10-3 shows the translation between the two formats. Finally, if the subject aircraft is controlled, then PIFR is set and a check of other pair records involving the subject aircraft is made to identify any internal pairs where only an uncontrolled threat has a resolution advisory. In such an instance, a potential incompatibility exists, and POSCMD is set to a negative value to force recomputation of the advisories for the internal pair.

5.3.4 Internal Pair Updating

The Internal Pair Updating Routine is flow charted in Figure 5-10. Its primary functions are to record the acceptance or

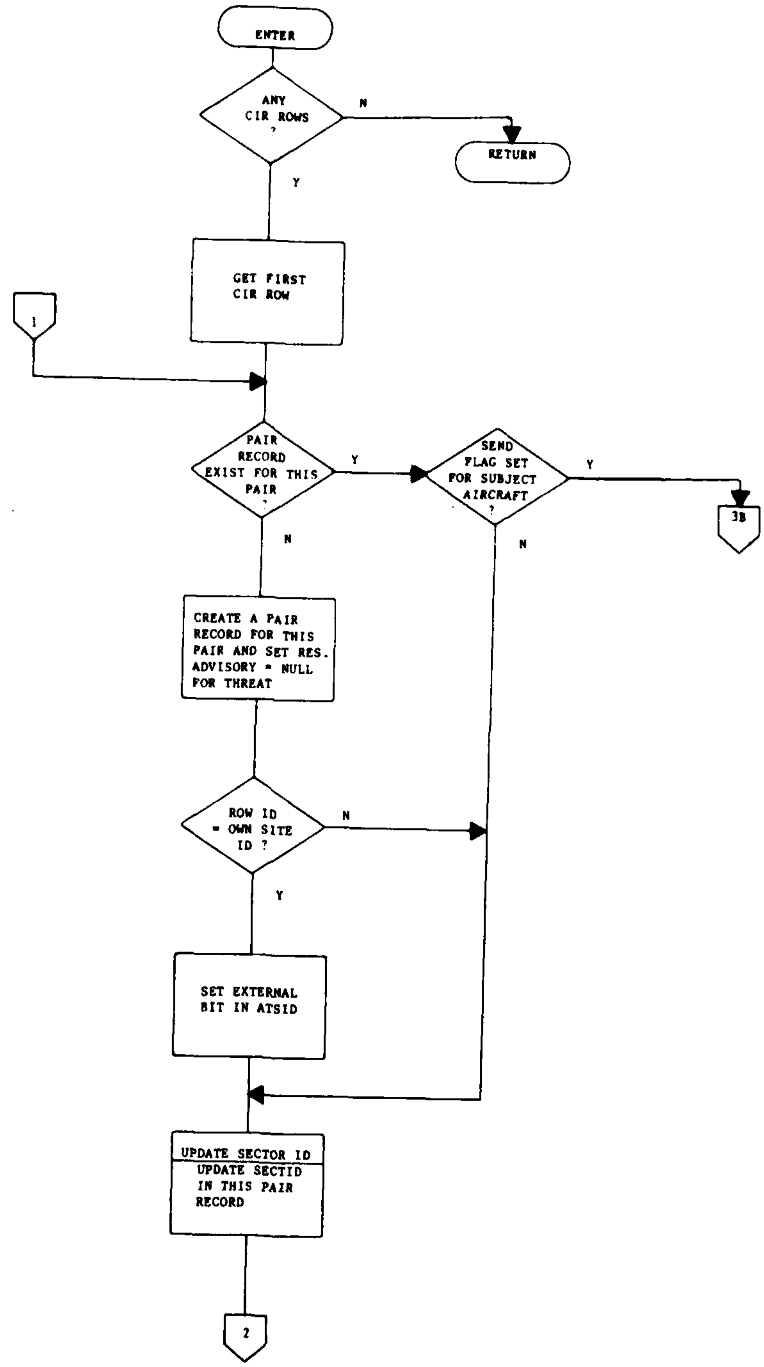


FIGURE 5-9
EXTERNAL PAIR UPDATING ROUTINE (Page 1 of 3)

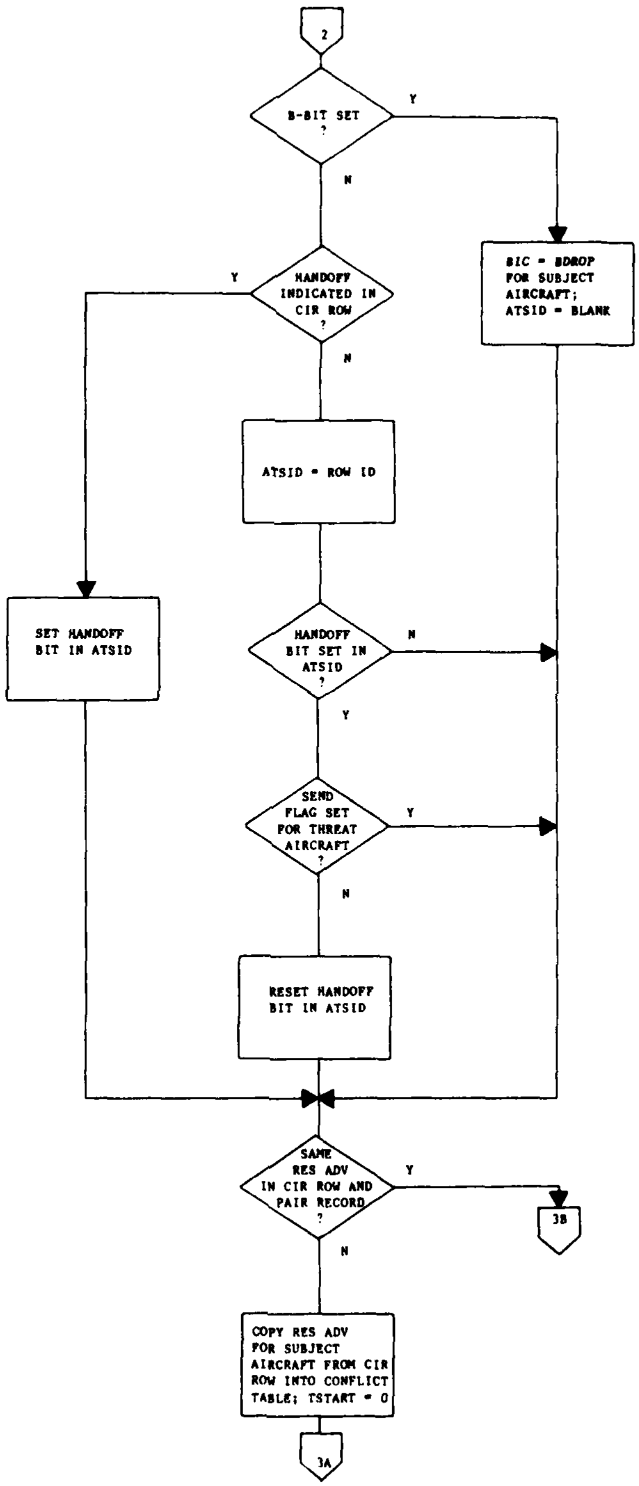


FIGURE 5-9
EXTERNAL PAIR UPDATING ROUTINE (Page 2 of 3)

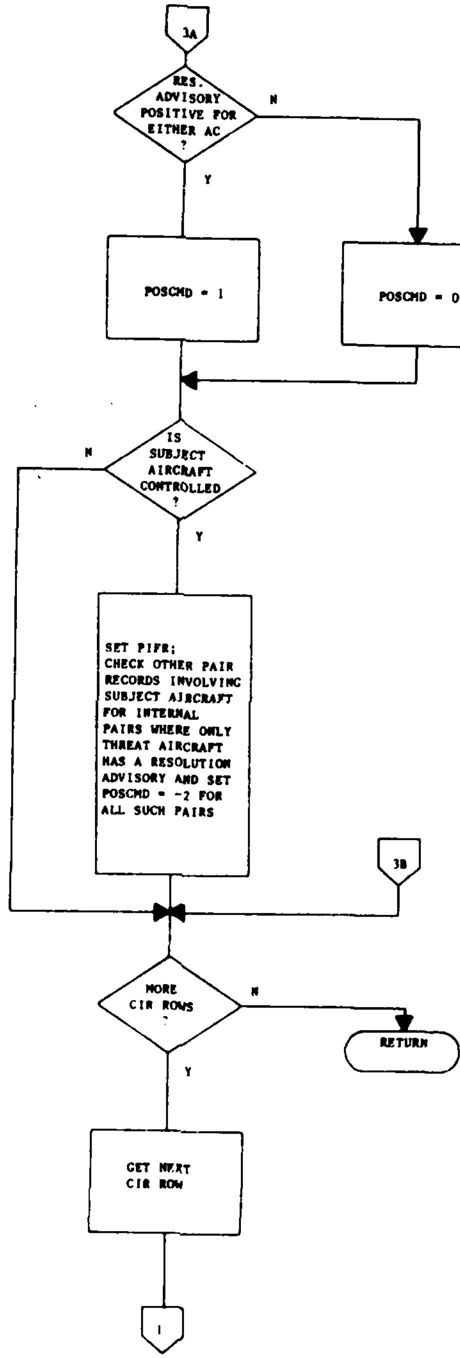


FIGURE 5-9
EXTERNAL PAIR UPDATING ROUTINE (Page 3 of 3)

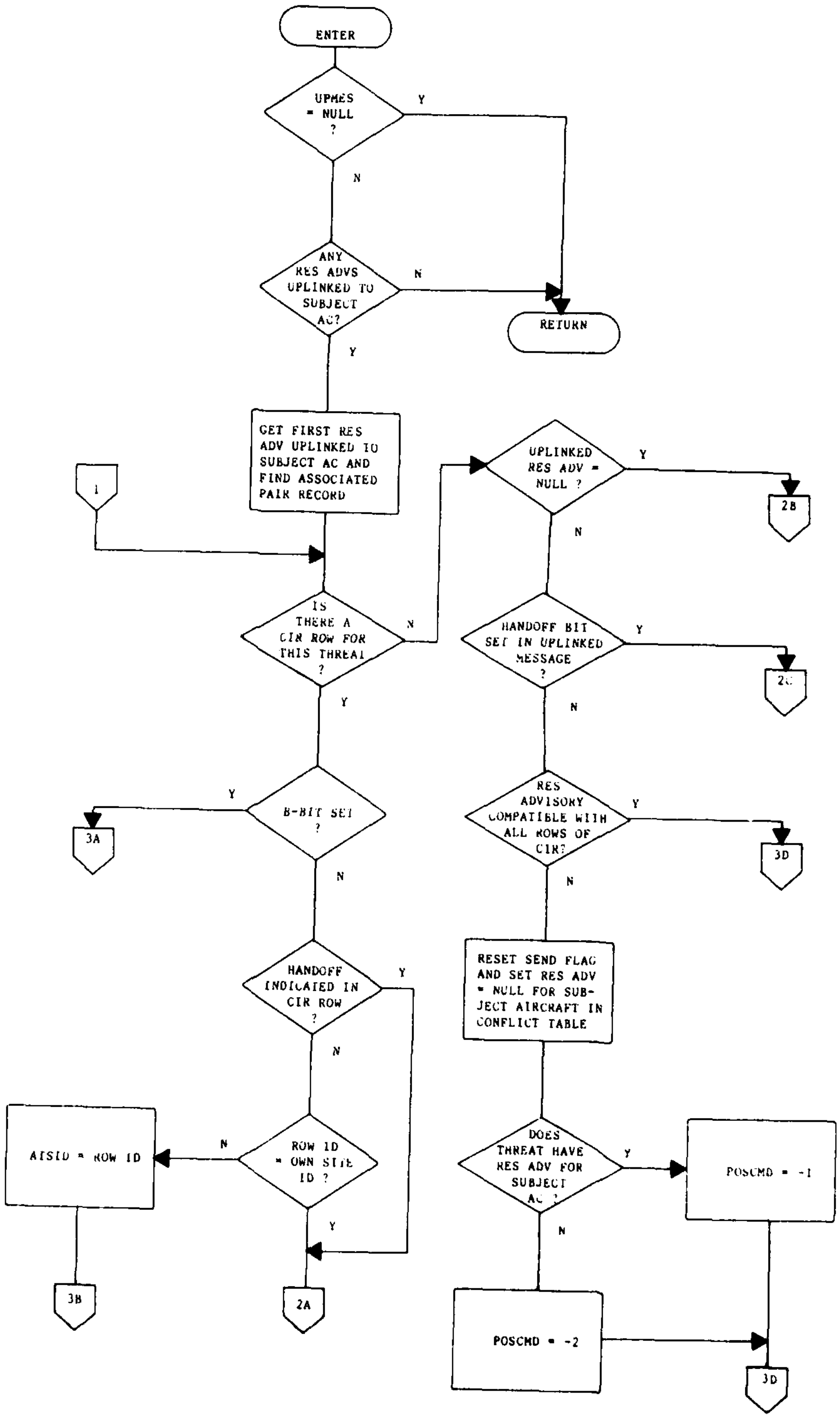


FIGURE 5-10
INTERNAL PAIR UPDATING ROUTINE (PAGE 1 OF 3)

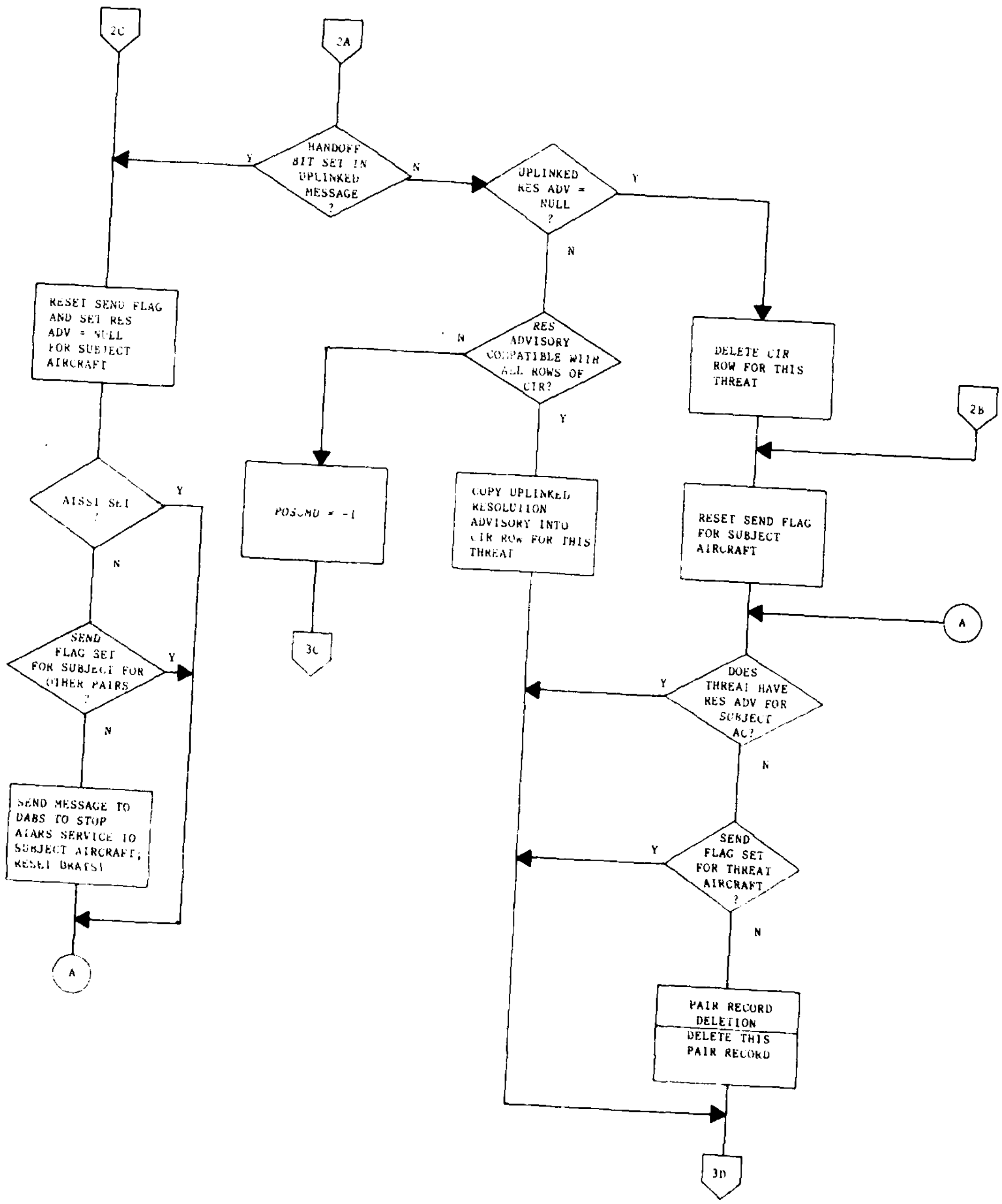


FIGURE 5-10
INTERNAL PAIR UPDATING ROUTINE (PAGE 2 OF 3)

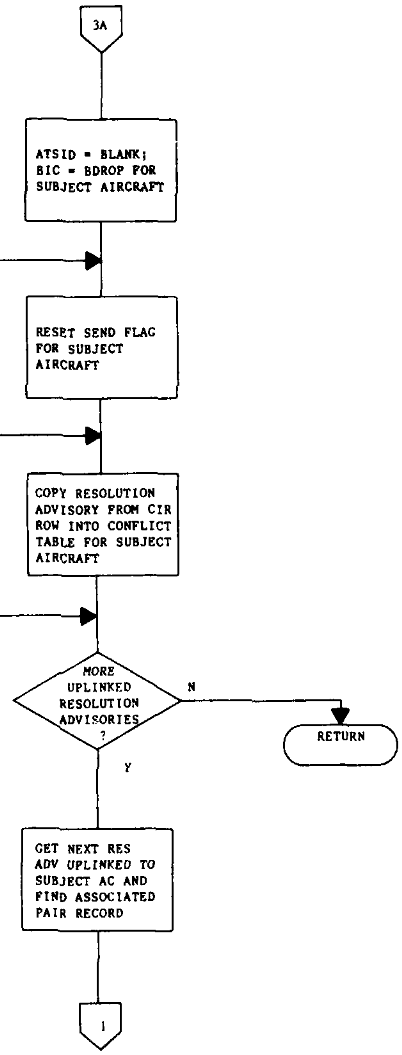


FIGURE 5-10
INTERNAL PAIR UPDATING ROUTINE (Page 3 of 3)

rejection of resolution advisories uplinked by the local site and to record the delivery of null resolution advisories and handoff messages. The uplinked resolution advisories are found (by locating the uplink message structure pointed to by UPMES1) and examined one at a time.

If a row already exists for the current threat and either the B-Bit is set or the row ID is not equal to the local site ID, then it is assumed that BCAS or another site stepped in first to resolve the conflict, and the pair record transitions to external status. As was pointed out earlier, the comparison and copying of resolution advisories from CIR rows and uplink messages on the one hand, and pair records on the other, implies a translation process. This translation is shown in Table 10-3.

If a handoff message has been accepted by the aircraft, this fact is recorded by resetting the SEND flag for the subject aircraft. If the aircraft is no longer in the local ATARS service zone and no more handoff messages are to be uplinked, a message is sent to DABS to stop ATARS service to the aircraft.

For most of the uplinked resolution advisories, the local site will have had the right to update the CIR. That is, either there was no previous CIR row, or the responsibility field (RRS) indicated local site responsibility or a handoff condition. For these cases, the uplinked advisory is checked for compatibility with all existing CIR rows. (See the compatibility table in Section 10.) If the uplinked resolution advisory is found to be incompatible (indicating rejection by the avionics), the conflict table is updated by restoring the previous advisory from the corresponding CIR row (if any). POSCMD is set to a negative value to force recomputation of the resolution advisories. If the uplinked advisory has been accepted, the advisory is copied into the CIR row (if any) in temporary storage. Acceptance of a null resolution advisory causes any existing CIR row to be deleted from temporary storage, the SEND flag to be reset for the subject aircraft, and the pair record to be deleted whenever possible. (The Pair Record Deletion Routine is described in Section 13.2.)

After the Internal Pair Updating Routine has been executed, the temporary storage area occupied by the downlinked CIR can be released.

5.3.5 Update Sector ID

The sector ID for internal pair records is normally initialized by the Master Resolution Task at the time of pair record creation

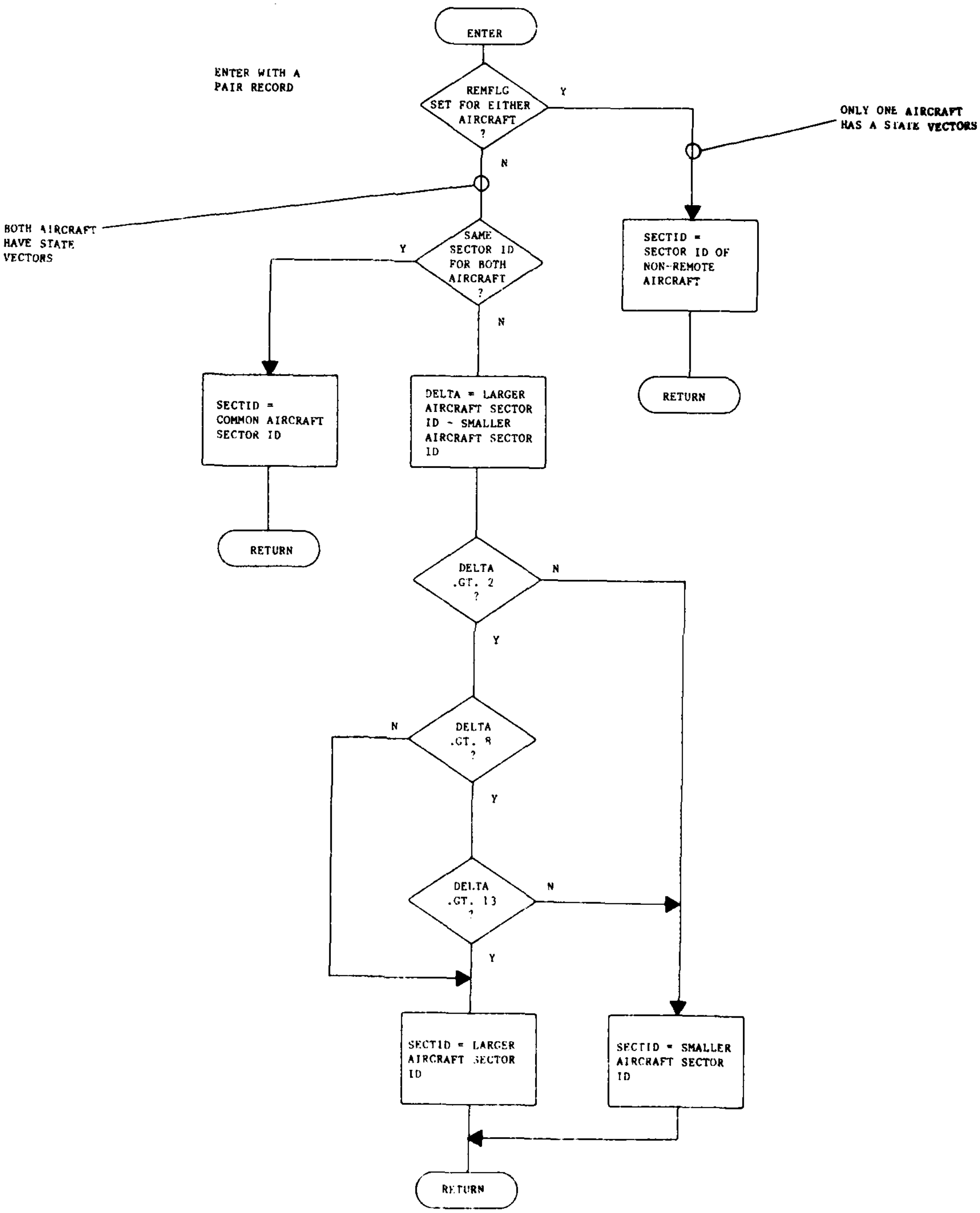


FIGURE 5-11
UPDATE SECTOR ID ROUTINE

and updated by the Seam Pair Task. For external pair records, however, SECTID is updated during CIR processing by the Update Sector ID Routine, shown in Figure 5-11. This routine always sets SECTID equal to the sector ID of one of the aircraft from its state vector. If only one aircraft has a state vector or if both aircraft are in the same ATARS sector, the choice is an easy one. If the aircraft are in different sectors, however, the following strategy is used: If the aircraft are less than three sectors apart, the leading (earlier) aircraft sector ID is chosen. If the aircraft are three or more sectors apart, the trailing (later) aircraft sector ID is picked.

6. AIRCRAFT PROCESSING

6.1 New Aircraft Processing

The selection of new aircraft to be added to the ATARS data base is made in the Report Processing and Track Processing Tasks. These choices are conveyed to the New Aircraft Processing Task through the XINIT list. The purpose of this module is to add all aircraft on this list to the X-list or EX-list and to initialize all parameters in the state vector that are used in subsequent ATARS processing tasks.

The XINIT list is a linked list of all aircraft that have been designated for addition to the X-list or EX-list by the Track Processing Task for a particular ATARS sector. This list has a pointer to the head of the list and is linked, in one direction only, through the NEXTX position in the state vectors. The use of NEXTX is legitimate at this time because this field is not used for those aircraft not yet added to the X-list or EX-list. In this module, aircraft from the XINIT list have their NEXTX and PREVX pointers set to include their state vectors in the forward and backward linked X-list or EX-list.

The flow chart of the New Aircraft Processing Task is given in Figure 6-1. This task uses the Initial Entry of Aircraft Into X-list/Ex-list Routine which is described in Section 6.4.1.

6.2 Aircraft Update Processing

The function of the Aircraft Update Processing Task is to update the position and velocity coordinates, determine the ATARS service zone through the Geographical Processing Routine (Section 6.3) and update the position on the X/EX-list (Section 6.4) of all aircraft in a particular sector as designated by the executive control. The position coordinates of the hub area aircraft are also updated as part of this task. The flow chart of the Aircraft Update Processing Task is given in Figure 6.2.

Aircraft update processing operates on a particular sector list of aircraft threaded in the X-list and EX-list. The start pointers (SIDSPX, SIDSPE) for the sector lists are in a table maintained by the executive control and are updated in the X/EX-list Update Routine (Section 6.4.2). The table contains all the start pointers for every sector on the X/EX-lists and null pointers for sectors which contain no aircraft. The start pointers identify the state vectors of the aircraft that starts the string of aircraft for a sector.

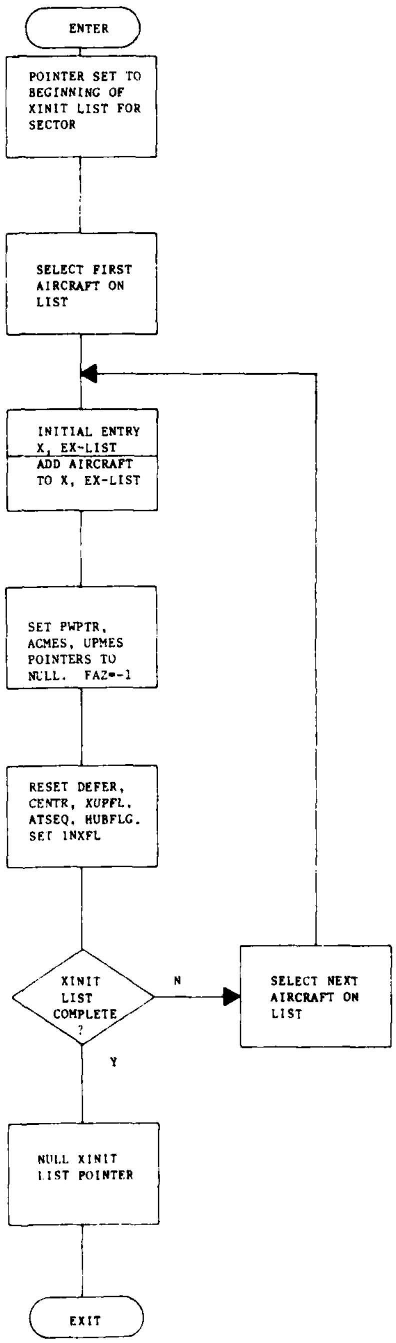


FIGURE 6-1
NEW AIRCRAFT PROCESSING TASK

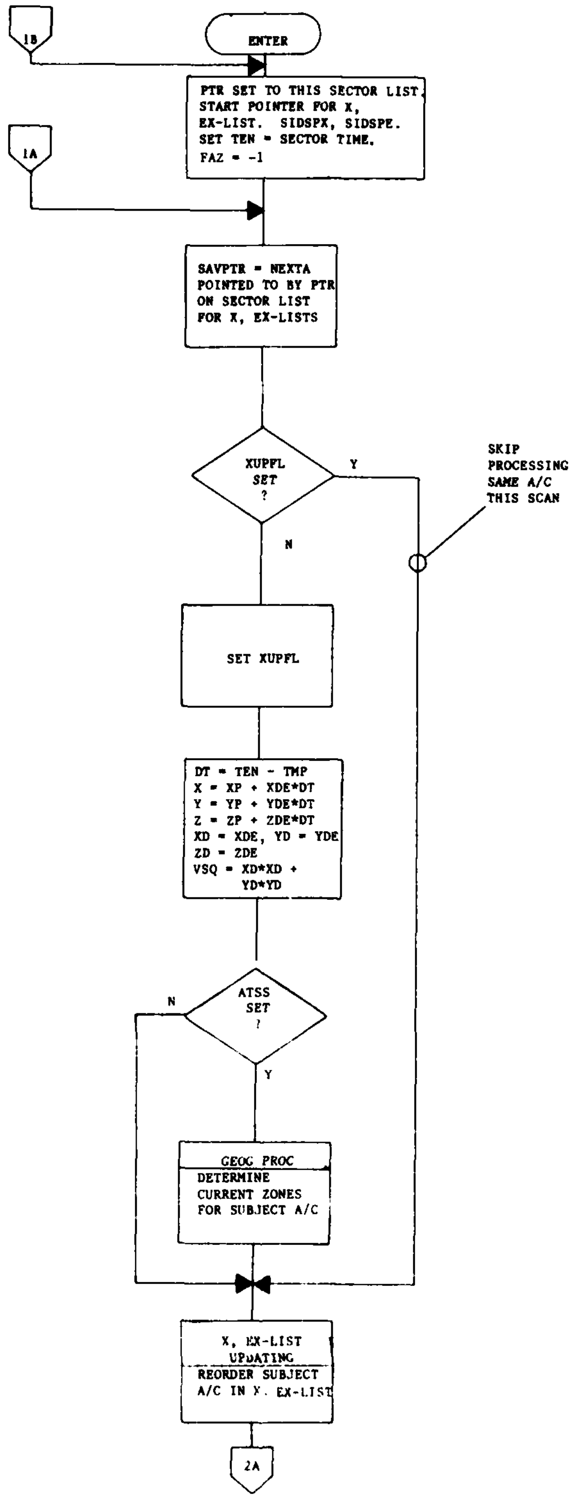


FIGURE 6-2
AIRCRAFT UPDATE PROCESSING TASK (Page 1 of 4)

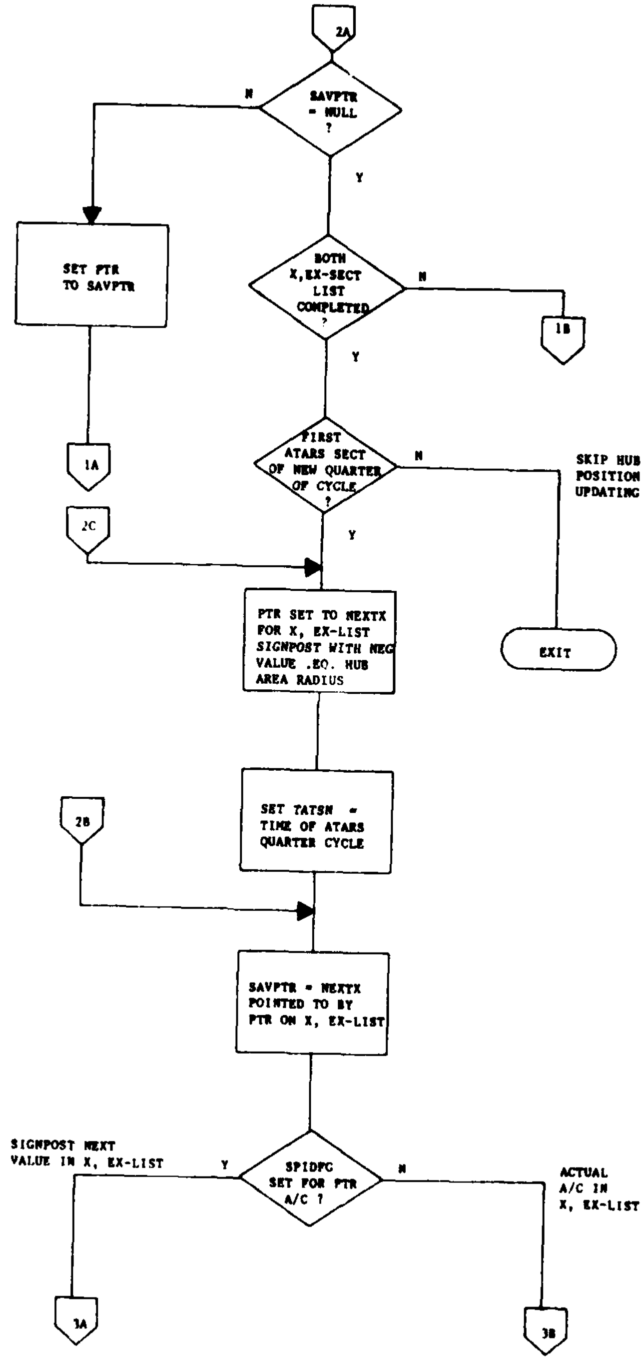


FIGURE 6-2
AIRCRAFT UPDATE PROCESSING TASK (Page 2 of 4)

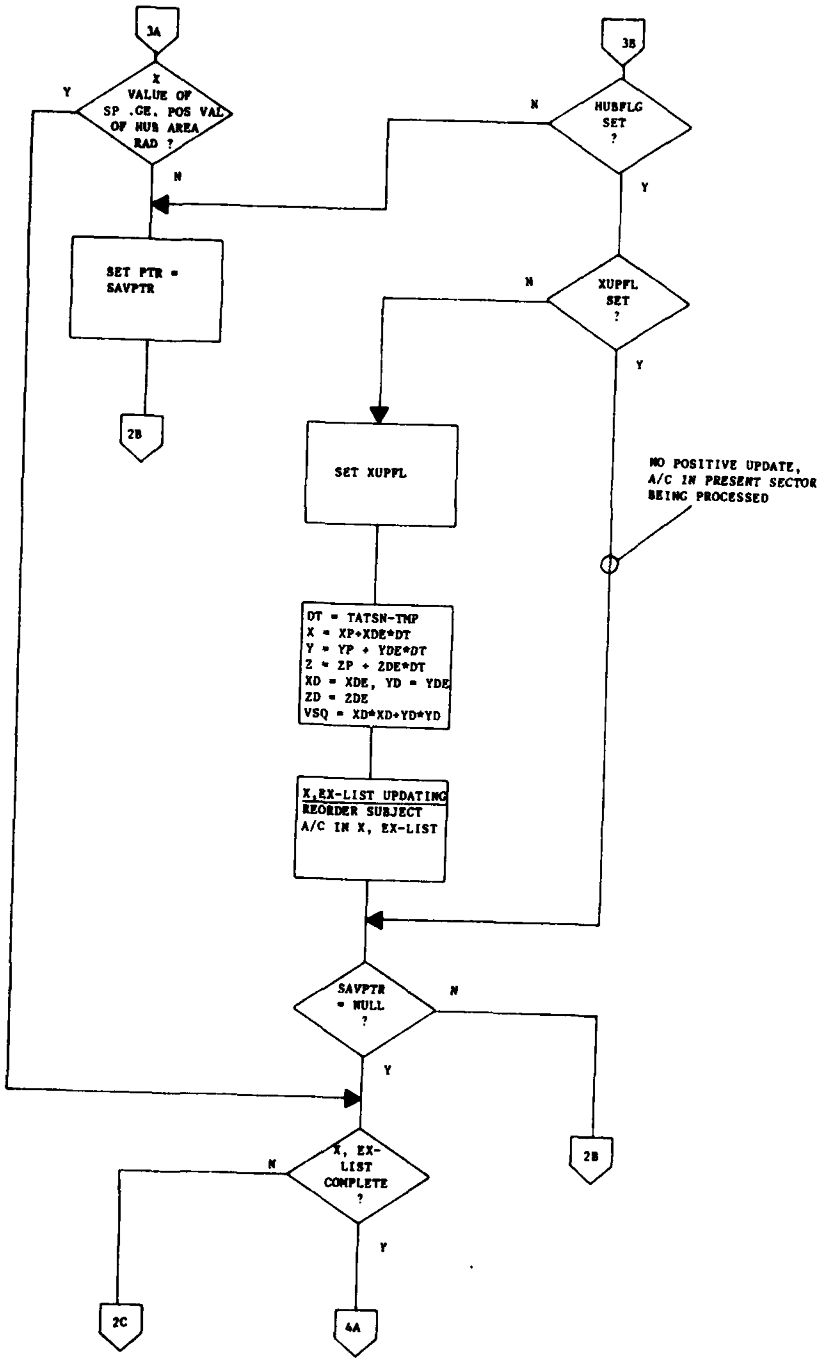


FIGURE 6-2
AIRCRAFT UPDATE PROCESSING TASK (Page 3 of 4)

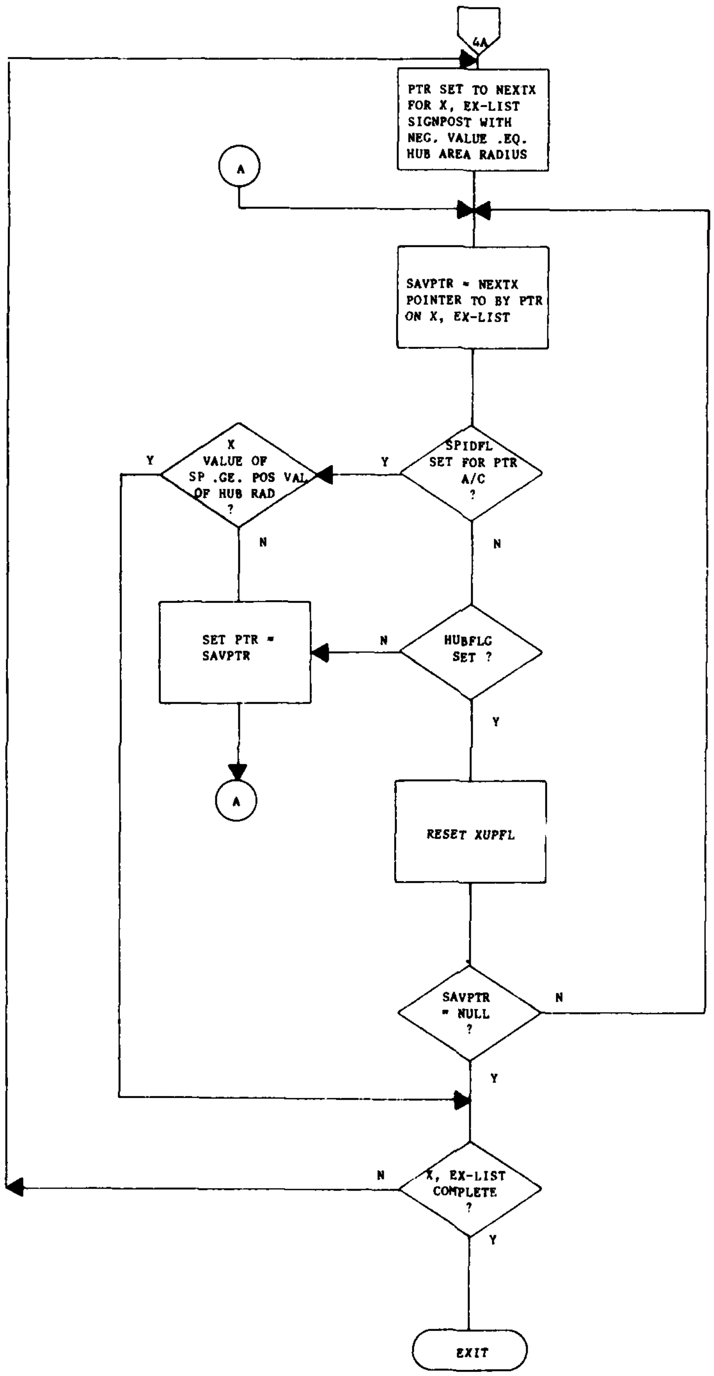


FIGURE 6-2
AIRCRAFT UPDATE PROCESSING TASK (Page 4 of 4)

The position coordinate update is achieved by a linear projection from the aircraft's predicted position, for a time equal to the difference between the sector time (TEN) and the aircraft time of prediction (TMP) using the aircraft external velocity components. All aircraft are then presented for sector processing on a common basis. It is important to note that the only coordinate used in ATARS sector processing after the Aircraft Update Processing Task is complete are the position (X,Y,Z) and velocity (XD,YD,ZD) coordinates set in this task. The updated coordinates are used to update the geographical zone if ATSS is set and the position in the X-list or EX-list for the subject aircraft before continuing with the next aircraft in the X-list or EX-list. This process continues until all aircraft in the sector thread for both the X-list and EX-list are completed.

The variables TEN and TMP will have a fixed number of bits. These variables will recycle to zero when the time overflows the number of available bits. Hence in subtracting time variables, here and throughout the ATARS processing both variables should be expressed with common higher order bits.

Special attention must be given to the structuring of the update processing task because the X/EX-list is used to access the aircraft for updating, but one of the steps in updating is to reposition the aircraft in the X-list. The next aircraft in the list is saved and stored in SAVPTR before the current aircraft is repositioned in the X-list. However, even with this procedure, an aircraft which has moved up the list by skipping one or more aircraft would be accessed a second time for updating in the same sector updating. To prevent this duplicate updating, the XUPFL in the state vector is set the first time the aircraft is accessed for updating and is read to prevent duplicate updating in the second access. The XUPFL flag is cleared once per sector when the aircraft is accessed in the Coarse Screen Processing Task.

The hub area position coordinate update is exercised at the start of every quarter cycle (i.e. when the antenna is at 0°, 90°, 180°, 270°). The hub area (Figure 3.2) is defined as a circle of given radius and centered at the DABS sensor. First, the signpost (explained in Section 6.4.1 - Initial Entry of Aircraft Into the X/Ex-list Routine) on the X/EX-list corresponding to the negative value of the hub area radius is located. The X/EX-list is searched forward until the signpost with the positive value of the hub radius is reached. All of the aircraft identified as being in the hub (HUBFLG set) on the X/EX-list between these negative and positive signposts are

afforded hub processing. The position and velocity coordinates of these aircraft are updated using the same technique described above for the regular sector aircraft position and velocity updating. This processing maintains a more current position on the X/EX-list for the aircraft located near the DABS sensor and in the area where ATARS sectors are not very wide. This is necessary because aircraft may change sectors rapidly in the hub area and this affords a more timely identification of a possible conflict in the ATARS processor.

Again, the XUPFL flag is used to prevent duplicate updating. The flag is reset in this task instead of waiting for the Coarse Screen Processing Task because the aircraft identified in the hub area may be from any sector, not just the particular sector being processed at the time. Therefore, not all the XUPFL flags would be reset on this pass through the ATARS processor.

6.3 Geographical Processing

This routine uses geographical mask functions to manage the ATARS service flag (ATSS1), BCAS lockout flag (BCLO), and BCAS service levels for suitably equipped aircraft. The masks controlling these services are tailored to each specific site. Special treatment is provided in the event of failure of a neighboring ATARS. The flow chart is shown in Figure 6-3.

6.3.1 ATARS Service Mask

An ATARS service mask contains the outer limits of the area of this site's ATARS service. Backup masks are stored corresponding to the failure of each neighboring site. These are selected by the backup mode logic of Section 15.9. The ATSS1 service flag is set for every aircraft in the service area. The flag is initially set by the Track Update Routine (Figure 4-8) when the aircraft first enters the service area.

The service mask should be implemented as a pair of convex polygons, one for aircraft from the lower limit of DABS coverage up to and including altitude HZONE, and the other for aircraft above altitude HZONE. These polygons may have as many vertices as are needed. For example, to implement multiple site coverage in a large area, intricate shapes may be required to provide the necessary overlap (seams) and divide the expected traffic and processing load.

It is essential that wherever two ATARS sites have a common boundary, their normal mode ATARS service areas overlap by a

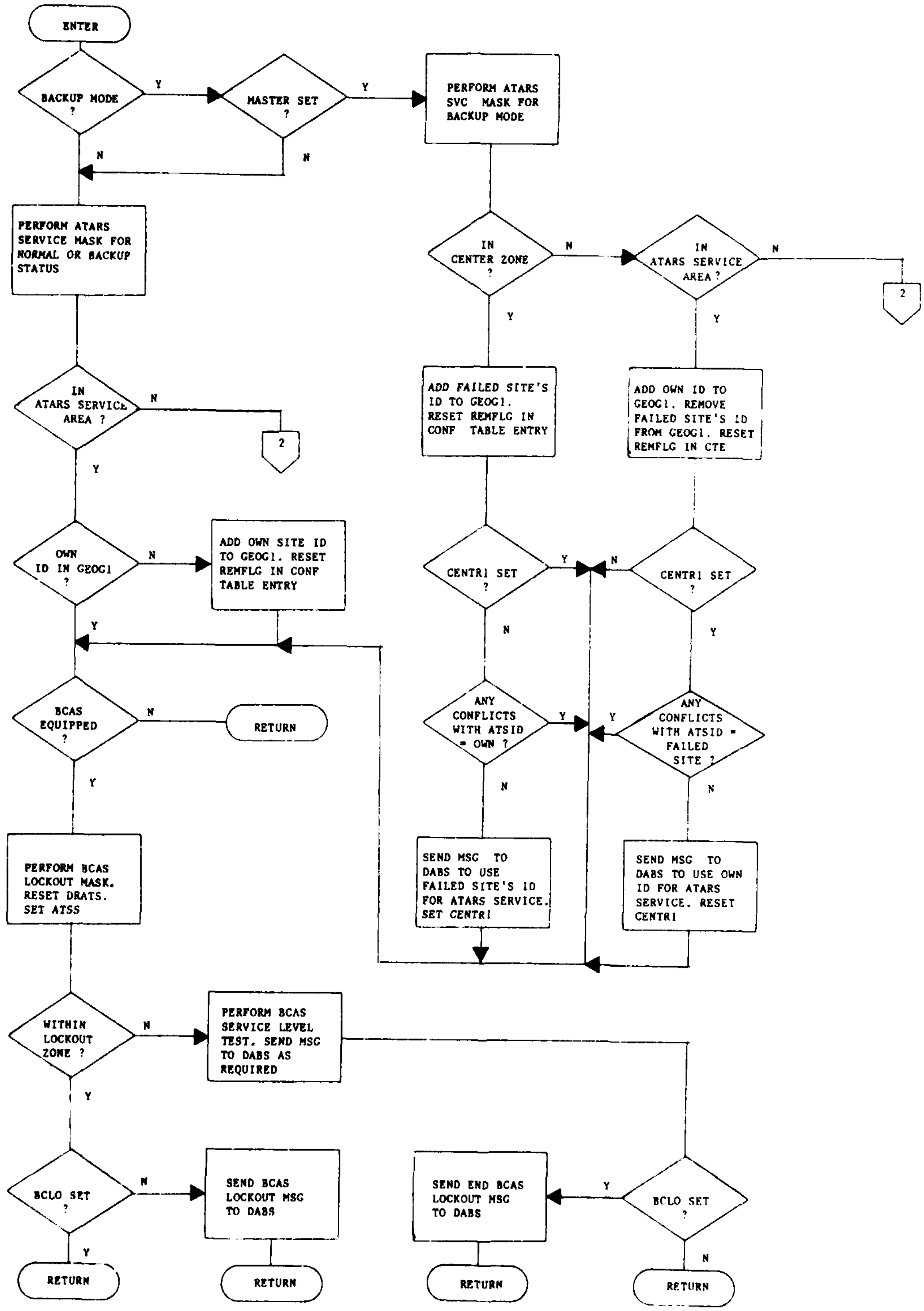


FIGURE 6-3
GEOGRAPHICAL PROCESSING ROUTINE (Page 1 of 2)

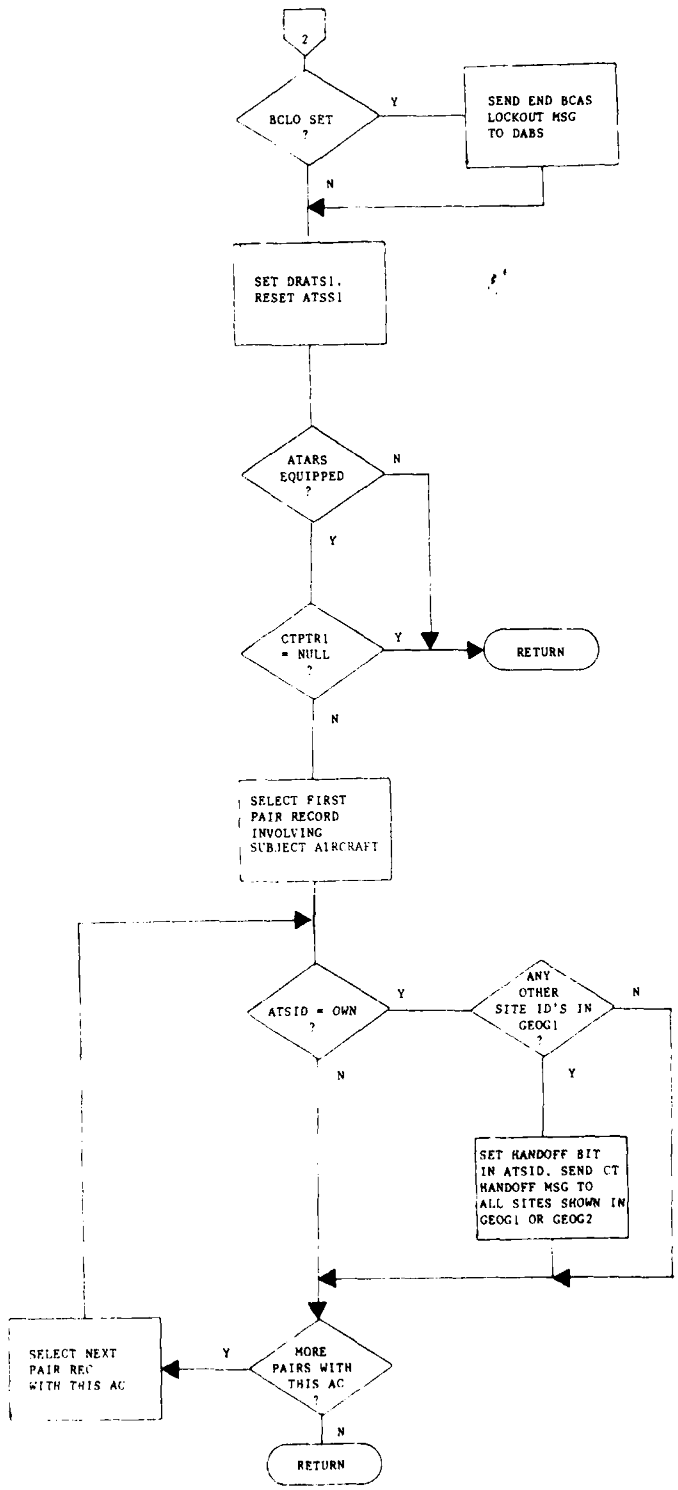


FIGURE 6-3
GEOGRAPHICAL PROCESSING ROUTINE (Page 2 of 2)

specified distance. This overlap is called a seam and is given a width sufficient to allow nominal warning time for any pair of aircraft on opposite sides of the boundary. The seam is implemented by extending each site's area a distance DSEAMH (or DSEAML) past the nominal boundary of the high (or low) altitude map. Then the sites' coverages overlap by 2*DSEAMH for the high altitude masks, as illustrated in Figure 6-4.

The following algorithm is suggested for use in determining whether the tracked aircraft position (XT, YT) lies within a convex polygon. This figure will be described by the NVERT vertices, (X_1,Y_1), (X_2,Y_2),...,(X_{NVERT},Y_{NVERT}). The vertices are numbered in a counterclockwise manner starting at any vertex as shown for the example 4-sided area of Figure 6-5. Form all vectors joining adjacent vertices in a counterclockwise direction as indicated by the vectors V_1 through V_4. Also form all vectors joining the vertices to the point (XT, YT). Let these vectors be designated VT_1 through VT_4. Then the point (XT, YT) is internal to the zone if and only if all vector cross products $VT_1*V_1, VT_2*V_2, \ldots, VT_{NVERT}*V_{NVERT}$, are negative. By precomputing several constants which are functions of the vertex coordinates, the number of calculations required to perform the test can be reduced.

A typical vector cross product, VT_i*V_i is,

$$VT_i = (XT-X_i)*(Y_{i+1}-Y_i)-(YT-Y_i)*(X_{i+1}-X_i).$$

This can be written,

$$VT_i*V_i = XT*DY_i - YT*DX_i+K_i$$

where,

$$DX_i = X_{i+1} - X_i$$
$$DY_i = Y_{i+1} - Y_i$$
$$K_i = Y_i*DX_i - X_i*DY_i$$

All the DX, DY and K constants for each map are precomputed and stored in memory. Then the expression,

$$XT*DY_i-YT*DX_i+K_i$$

is evaluated repeatedly from i= 1 to NVERT. If any expression is positive, the aircraft is outside the polygon. If all are negative, it is inside.

6.3.2 The Geographical Zone Indicator (GEOG)

The site ID bits in an aircraft's CIR provide a current indication of the sites providing ATARS service. These bits

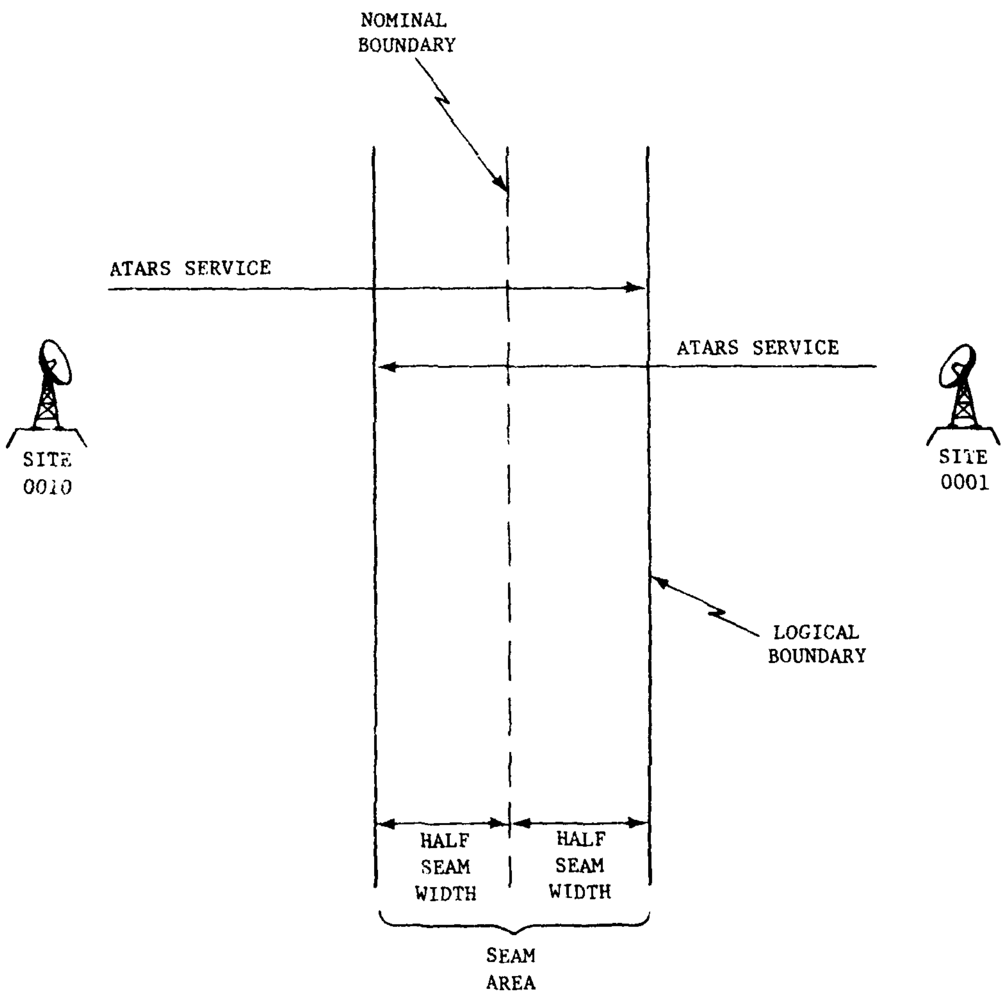


FIGURE 6-4
SEAM BETWEEN ADJACENT SITES

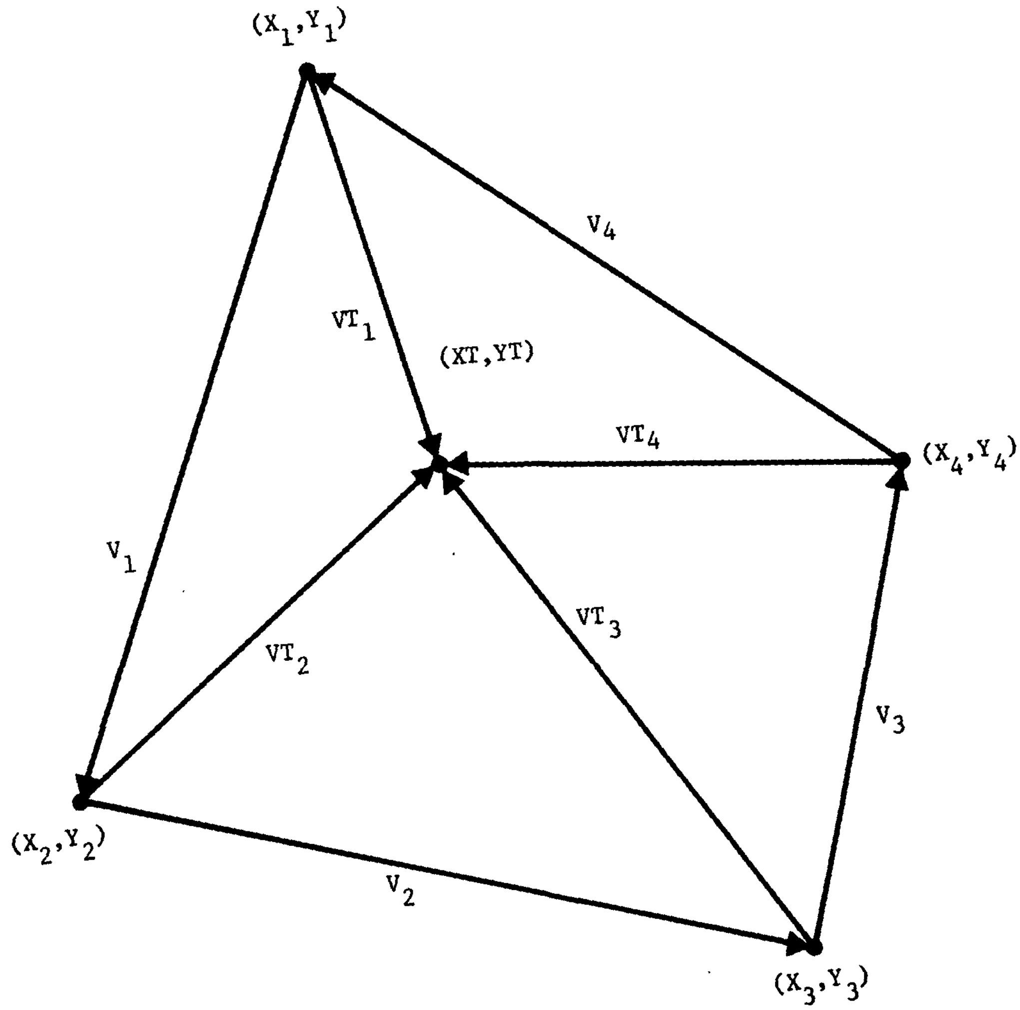


FIGURE 6-5
DETERMINING WHETHER THE POINT (XT, YT)
LIES WITHIN A POLYGON

allow determination of the aircraft's placement in a seam between two (or more) sites. The site ID bits are read in CIR processing (Section 5.3) and saved in GEOG1. The geographical routine looks for own-site ID in GEOG1. If it has not yet been uplinked, it is added to GEOG1 anyway, to enable the seam pair test to accept pairs involving this aircraft.

If an adjacent site has failed and own-site is the "master" site for this failure, own-site continues to use the failed site's ID in a "center" zone. An additional masking locates aircraft in the proper area and either own or failed site's ID is put into GEOG1. Note that own ID is not removed from GEOG1 when the aircraft is in the center area, for own ID in this case may be due to a remote site beyond the center area with the same ID as own-site.

When a BCAS equipped aircraft (indicated in ATSEQ1) is inside the ATARS zone, another mask is performed for the BCAS lockout zone. BCAS is locked out inside most of the ATARS area, but is enabled near its boundary to give protection from "pop-ups" *unseen* by ATARS. The Start/End BCAS Lockout Messages to DABS control the lockout status in DABS' surveillance file. These messages need not be repeated every scan.

When an aircraft previously inside the ATARS zone is first detected outside the zone by geographical processing, ATSS1 is reset and the coarse screen function inhibits further conflict pair detection. DRATS1 is set to notify other tasks that the aircraft is still "visible" and able to receive handoffs. If the aircraft was involved in any seam conflicts controlled by own-site, the handoff bit is set in ATSID and the adjacent sites indicated in either GEOG1 or GEOG2 are notified by ground line. Conflict pair removal will remove these pair records when appropriate. Own ID is still retained in ATSID to indicate to seam pair test that the handoff was from own-site, and acceptance of the pair is not allowed.

6.4 X-List/EX-List Updating

The X/EX-lists are two lists of aircraft which are ordered on the X-coordinates of the aircraft with the DABS sensor as the center point. The X-list includes all aircraft whose altitude is below the threshold altitude, ALO, and whose speed squared is below the limit SPLO2. All other aircraft are on the EX-list. The position of the aircraft on these two lists is checked when the particular ATARS sector is being processed and it is updated if required. The Initial Entry of Aircraft Into the X/EX-list

Routine (Section 6.4.1) and X/EX-list Updating Routine (Section 6.4.2) describe the process of placing aircraft on the lists and maintaining their current position on the lists.

6.4.1 Initial Entry of Aircraft Into the X/EX-Lists

Both the X-list and EX-list are modified to permit expeditious entry of new aircraft into the ordered list. This modification takes the form of seeding the ordered X/EX-list with the dummy state vectors which have fixed X coordinates. A cross-reference permits a direct means of locating the dummy state vector corresponding to a given X coordinate. The cross-reference takes the form of an array of pointers linking the known X coordinates. The dummy state vectors are called signposts and contain, as a minimum, fields for the NEXTX and PREVX pointers, a field for the X value of the signpost, and a field for the flag to identify signposts, SPIDFG. SPIDFG will be permanently set for all signposts and reset for all aircraft state vectors. This flag is used to expedite signpost identification in the Coarse Screen Processing Task.

The procedure for entering a new aircraft into the X-list or EX-list is shown in Figure 6-6. A determination is first made if the aircraft is in the hub area. If so, the hub flag (HUBFLG) is set. If the aircraft qualifies for the EX-list, the aircraft is entered on the EX-list, and the EXFLG flag is set; otherwise, it is entered on the X-list and the EXFLG flag is reset. Both the X-list and EX-list initially consist only of the signposts linked together. The NEXTX and PREVX pointers of the two terminal signposts in both lists are set to null. All aircraft may be entered into the X-list or EX-list by successive use of this procedure.

The new aircraft are linked to the particular ATARS sector list in the X/EX-list corresponding to the sector identification (SVSID).

The ATARS sector thread is linked only in the forward direction using a pointer NEXTA. If the new aircraft become the first aircraft in a sector thread, the executive program must be notified so that the SIDSPX and SIDSPE table is updated to reflect this change. When threading in new aircraft to a sector list, care must be taken to remember the previous aircraft position on the list, as a backwards pointer is not required for the ATARS processing and thus not maintained as part of the state vector.

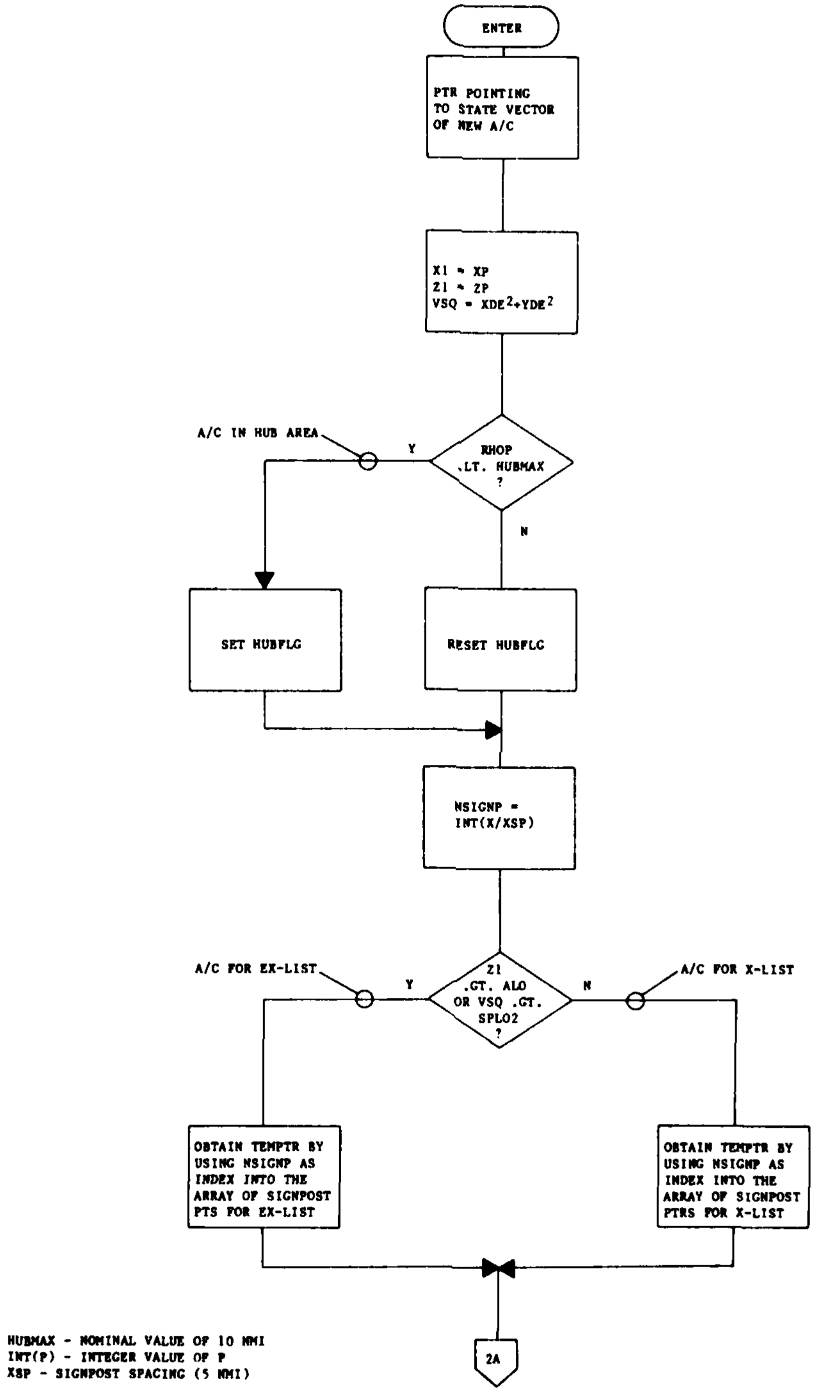


FIGURE 6-6
INITIAL ENTRY OF AIRCRAFT INTO X-LIST/EX-LIST ROUTINE (Page 1 of 3)

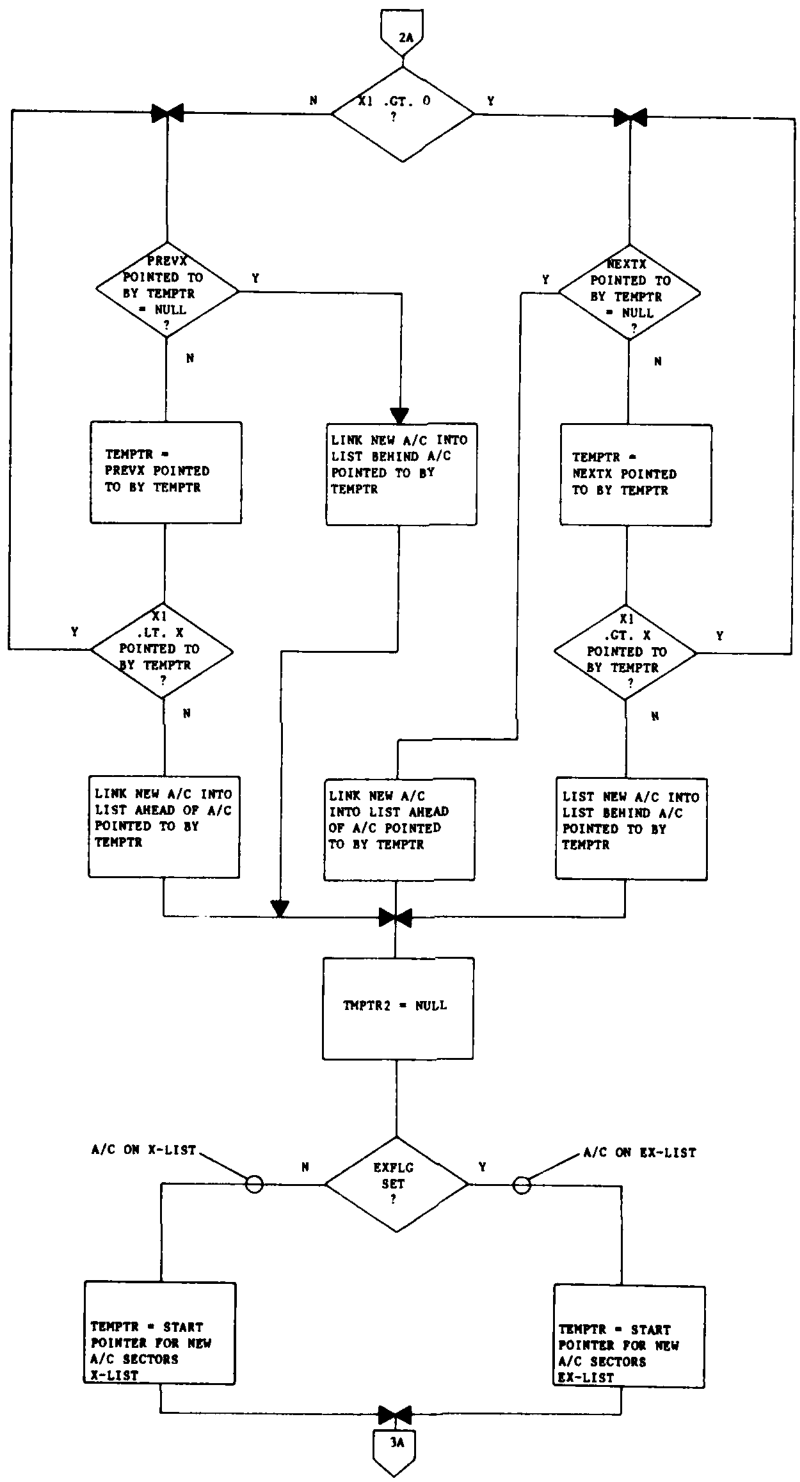


FIGURE 6-6
INITIAL ENTRY OF AIRCRAFT INTO X-LIST/EX-LIST ROUTINE (Page 2 of 3)

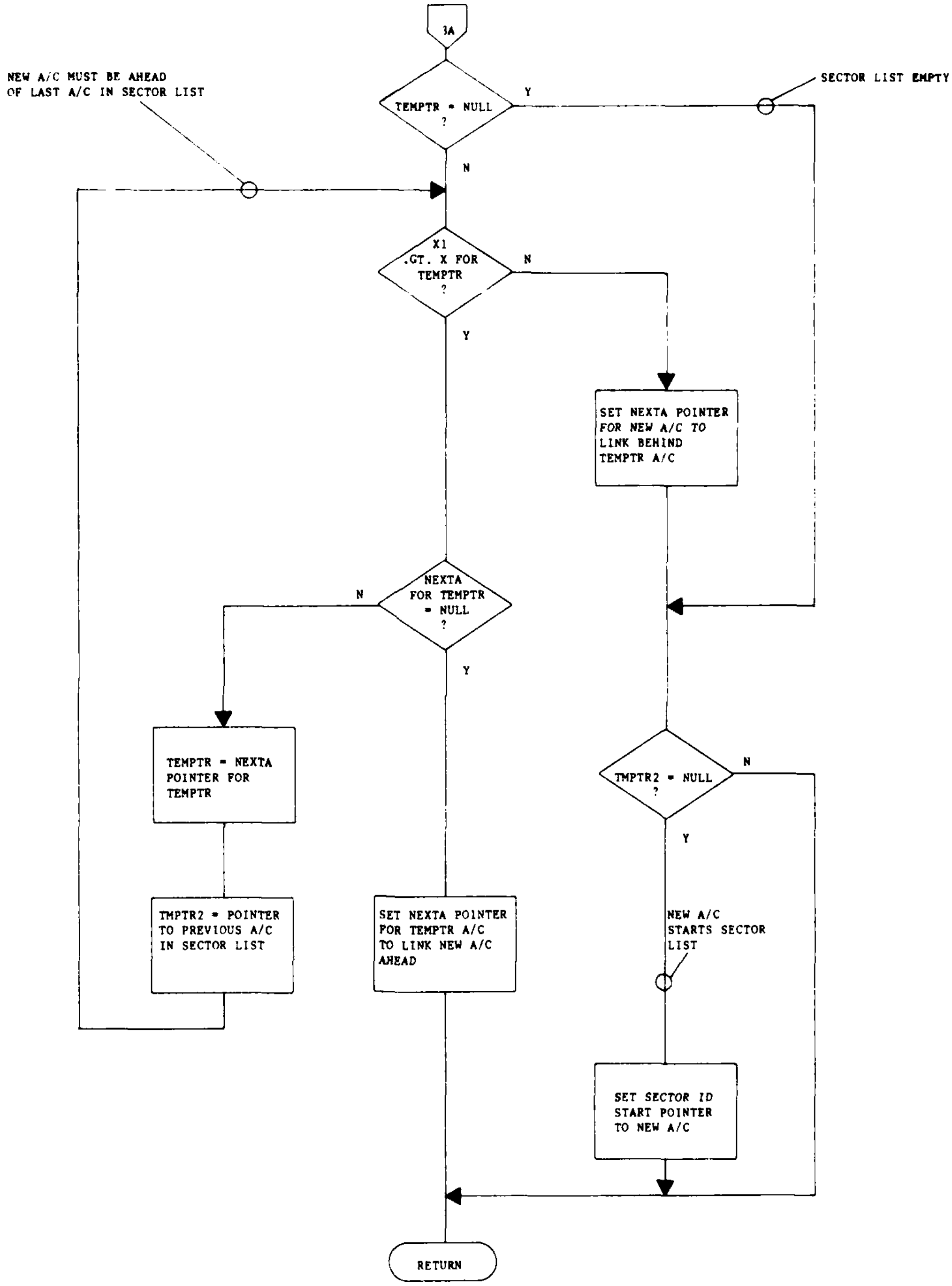


FIGURE 6-6
INITIAL ENTRY OF AIRCRAFT INTO X-LIST/EX-LIST ROUTINE (Page 3 of 3)

6.4.2 X-List/EX-List Updating

The procedure for updating the X/EX-lists is shown in Figure 6.7. The EXFLG (set for the EX-list aircraft) is used to determine on which list an aircraft appeared on the last cycle. If the aircraft has crossed the altitude or speed threshold, then that aircraft is removed from the X-list or EX-list and entered into the other list using the Initial Entry of Aircraft Into the X/EX-list Routine (Section 6.4.1). If the aircraft has not crossed the thresholds, then its position in the X/EX-list is updated according to its present X coordinate. At the same time, the aircraft position in the ATARS sector list is updated to correspond to the present X coordinate. If the new position in the sector list is the first position in the sector list, the executive program must be notified to set SIDSPX or SIDSPE correctly.

6.5 Coarse Screen Processing

The Coarse Screen Processing Task is an operation applied to a single aircraft on the X-list or the EX-list. The executive program points to the initial aircraft for a particular sector's list on the X/EX-list and coarse screening then steps through the list, processing all the aircraft on the sector list. The purpose of coarse screen filtering is to identify aircraft which may be in conflict with the subject aircraft. This is done by computing X, Y, and Z search limits for a sector subject aircraft and then testing all aircraft in the appropriate linked list, which fall within the X-limit against the Y and Z search limits, and a Z rate test. By segregating aircraft through the use of the X-list and the EX-list, it is possible to construct a coarse screening procedure that can provide ample warning times for aircraft with exceptionally high speeds (those on the EX-list) without requiring unnecessarily large search volumes for the majority of the aircraft which are on the X-list.

The ATARS program uses larger look-ahead times for pairs involving controlled aircraft than for pairs involving only uncontrolled aircraft. Since the greatest number of aircraft is expected to be uncontrolled, a significant savings in computational requirements is achieved by using a separate coarse screening procedure with larger search limits for controlled aircraft. For coarse screening of uncontrolled subject aircraft on the X-list, only other uncontrolled aircraft with X coordinates greater than the X coordinate of the subject aircraft are

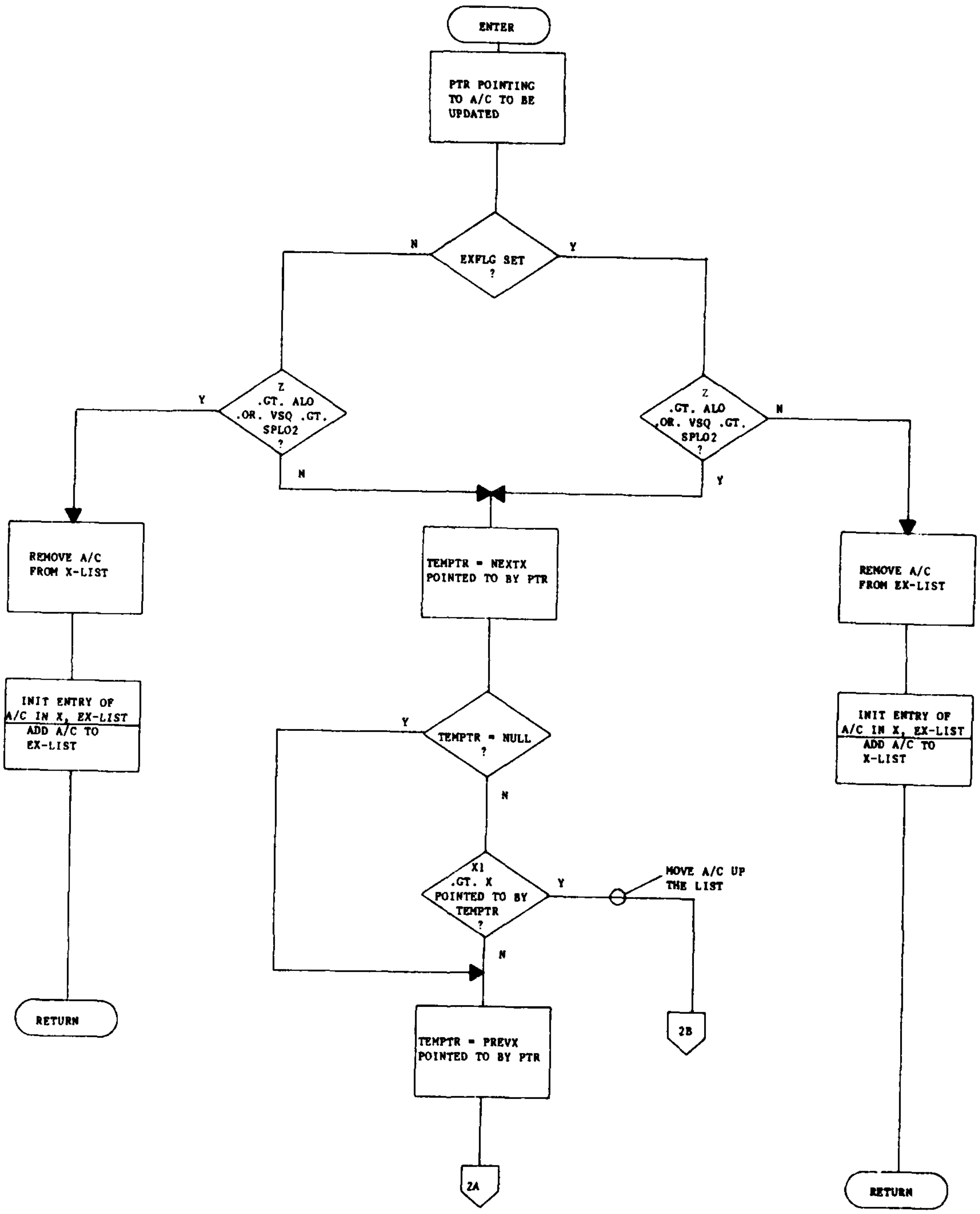


FIGURE 6-7
X-LIST/EX-LIST UPDATING ROUTINE (Page 1 of 3)

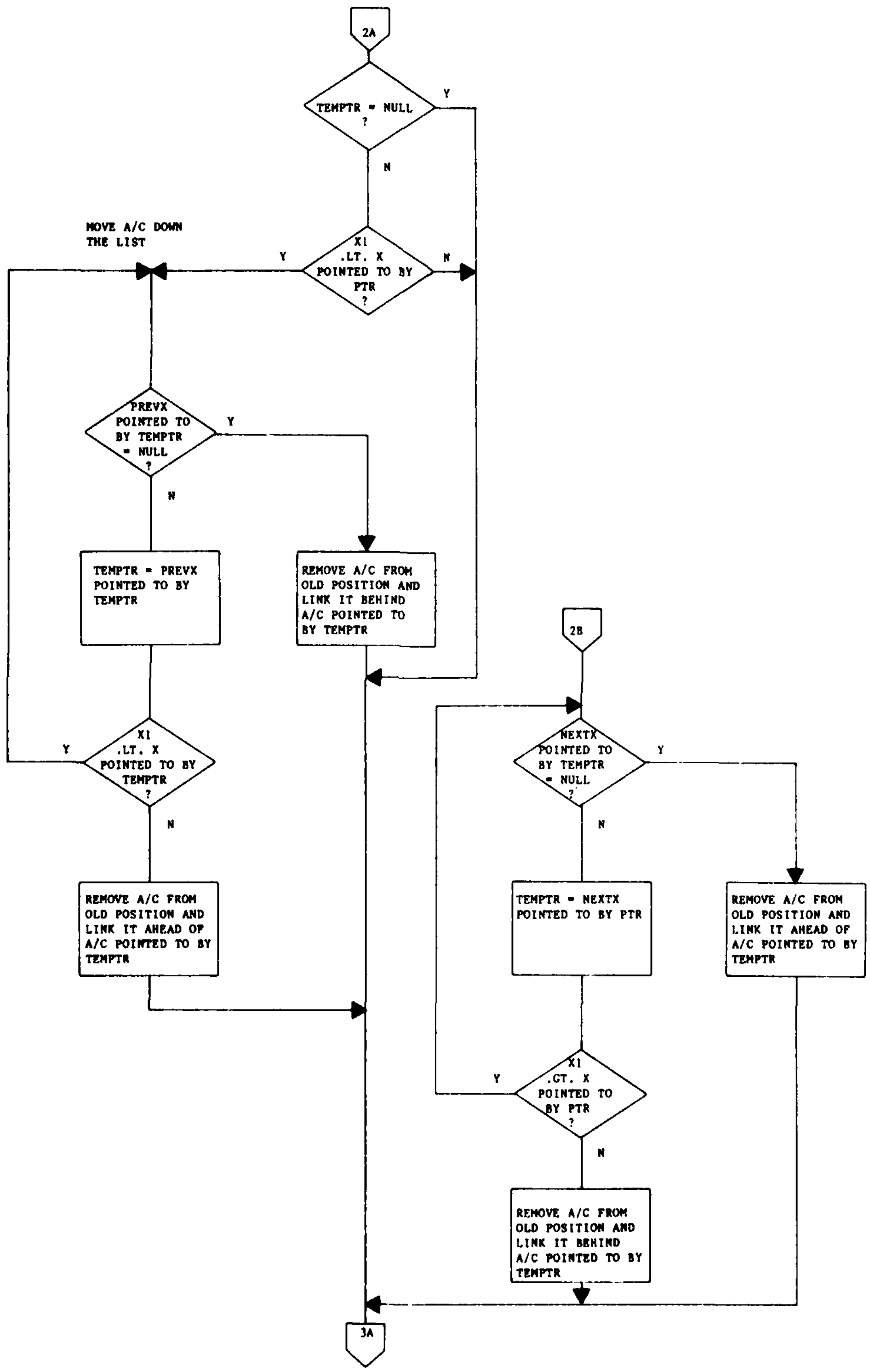


FIGURE 6-7
X-LIST/EX-LIST UPDATING ROUTINE (Page 2 of 3)

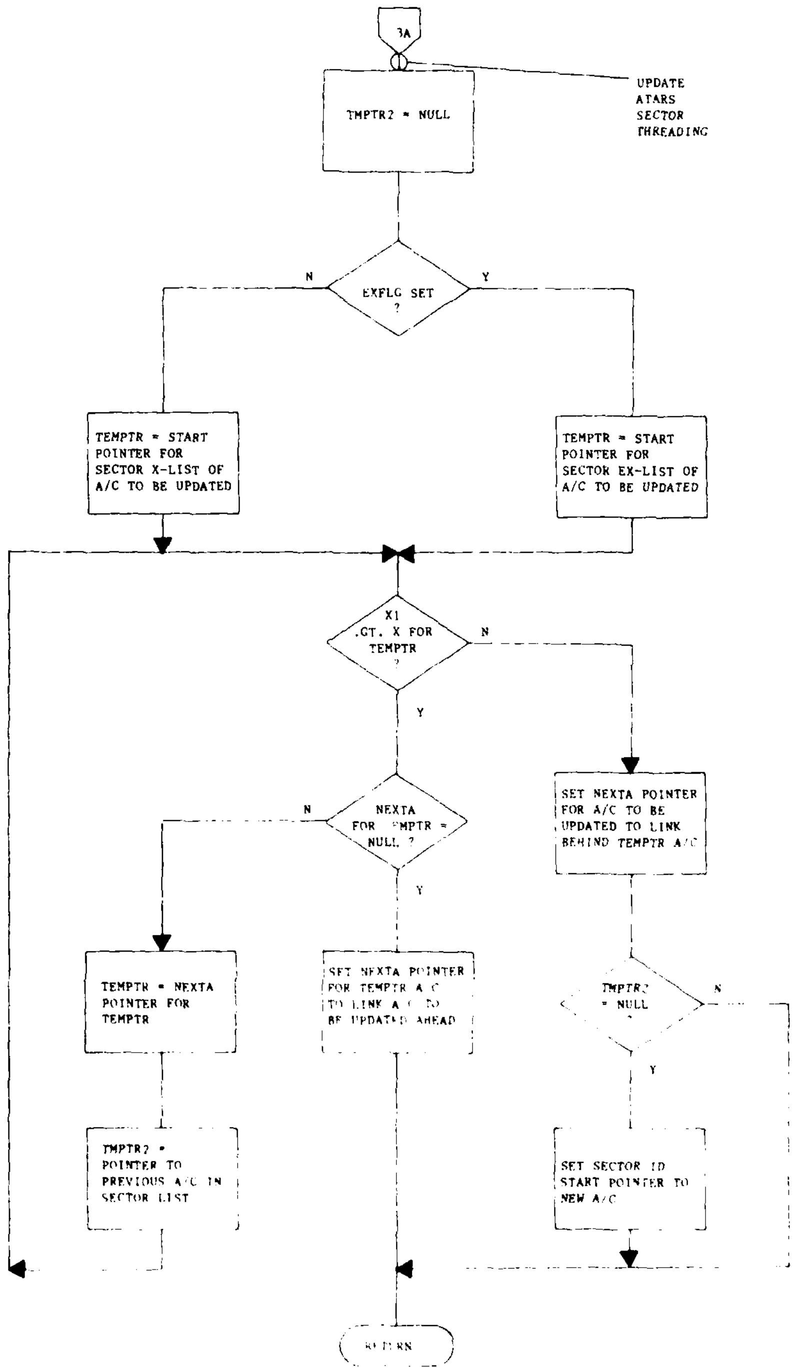


FIGURE 6-7
X-LIST/EX-LIST UPDATING ROUTINE (Page 3 of 3)

examined. This constitutes a one-way search, in which only uncontrolled/uncontrolled potential conflicts are investigated. For controlled subject aircraft, a two-way search of the X-list is used. When the search is made in the positive X direction, all controlled and uncontrolled aircraft are investigated, and when the search is made in the negative X direction, only the uncontrolled aircraft are investigated. This avoids a duplicate declaration of controlled/controlled conflicts. The overall process is shown for the X-list and the EX-list aircraft in Figure 6-8.

As shown in Figure 6-9, the search region implied by a given aircraft is computed as the outer bounds of either:

1. a region given by the coarse screen proximity advisory search criterion (this region is the same for both a controlled and an uncontrolled subject aircraft) or

2. a region based on a time projection using the subject aircraft tracked velocities and the largest look-ahead time appropriate for the subject aircraft, and assuming the intruding aircraft to have maximum velocity (240 knots low altitude, 600 knots high altitude).

The search limits so obtained will then permit detection of proximity advisories or any of the other messages which are based on the tau criterion. For the nominal values of parameters given in Figure 6-9, a 240 knot maximum speed has been assumed.

The detailed flow chart of the Coarse Screen Processing Task is shown in Figure 6-10. Parameters and variables used in Figure 6-10 are listed in Tables 6-1 and 6-2. The coarse screen resets the XUPFL flag for the subject aircraft which is used in the Aircraft Update Processing Task to prevent multiple updates during repositioning of aircraft on the X/EX-lists. It is convenient to do this in coarse screening when each aircraft in the sector list is being accessed for coarse screening, rather than requiring a separate pass through the X-list and EX-list specifically to reset this flag.

Coarse screening involves searching along a linked list from the position of the aircraft undergoing coarse screening to the upper and lower (if appropriate) X-limit. X-list aircraft are checked against other X-list aircraft only. EX-list aircraft are checked against EX-list aircraft and, if their altitude and vertical rate warrant, against X-list aircraft. By using the signpost identifier flag (SPIDFG), subject aircraft do not have

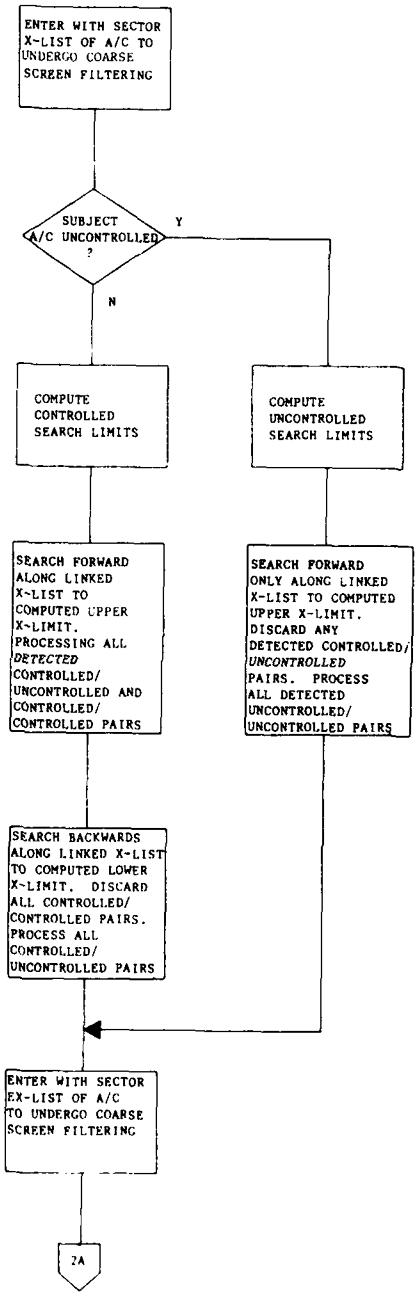


FIGURE 6-8
DESCRIPTION OF COARSE SCREEN PROCESSING TASK (Page 1 of 2)

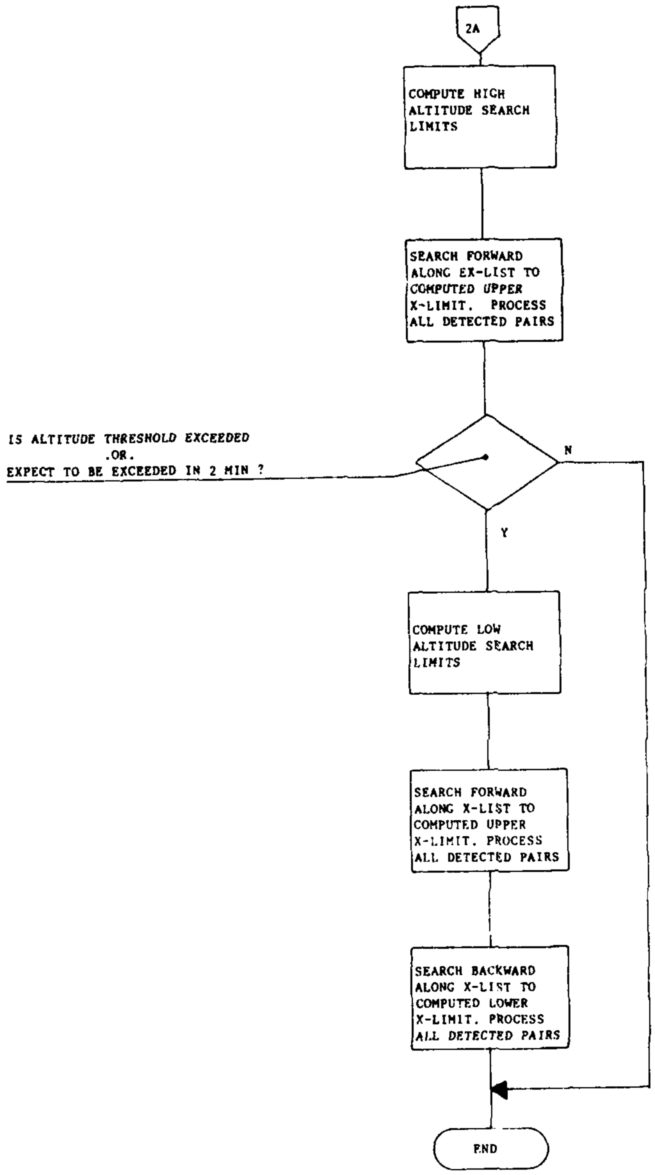
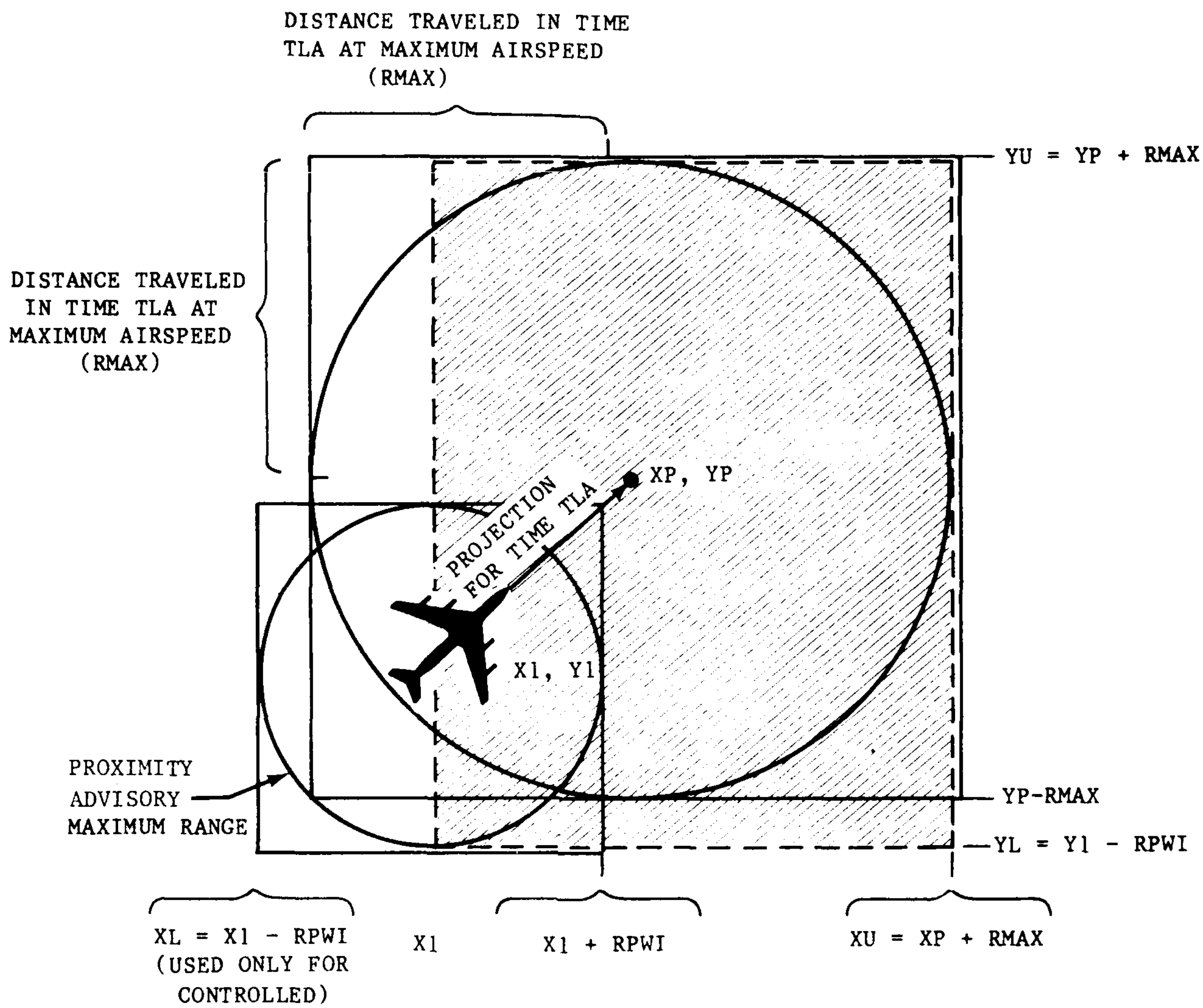


FIGURE 6-8
DESCRIPTION OF COARSE SCREEN PROCESSING TASK (Page 2 of 2)



WHERE :	TLA	-	TLV FOR UNCONTROLLED AND TLI FOR CONTROLLED
	TLV	-	LONGEST LEAD TIME FOR UNCONTROLLED (75 SEC)
	TLI	-	LONGEST LEAD TIME FOR CONTROLLED (120 SEC)
	RMAX	-	RMAXV FOR UNCONTROLLED AND RMAXI FOR CONTROLLED
	RMAXV	-	MAXIMUM RANGE OVER LONGEST LOOK AHEAD TIME FOR UNCONTROLLED (5 NM)
	RMAXI	-	MAXIMUM RANGE OVER LONGEST LOOK AHEAD TIME FOR CONTROLLED (8 NM)
	RPWI	-	LARGEST SEPARATION BETWEEN AIRCRAFT FOR A PROXIMITY ADVISORY ASSUMING BOTH AIRCRAFT AT MAXIMUM SPEED (4 NM)

FIGURE 6-9
SEARCH REGION FOR COARSE SCREENING OF UNCONTROLLED AIRCRAFT

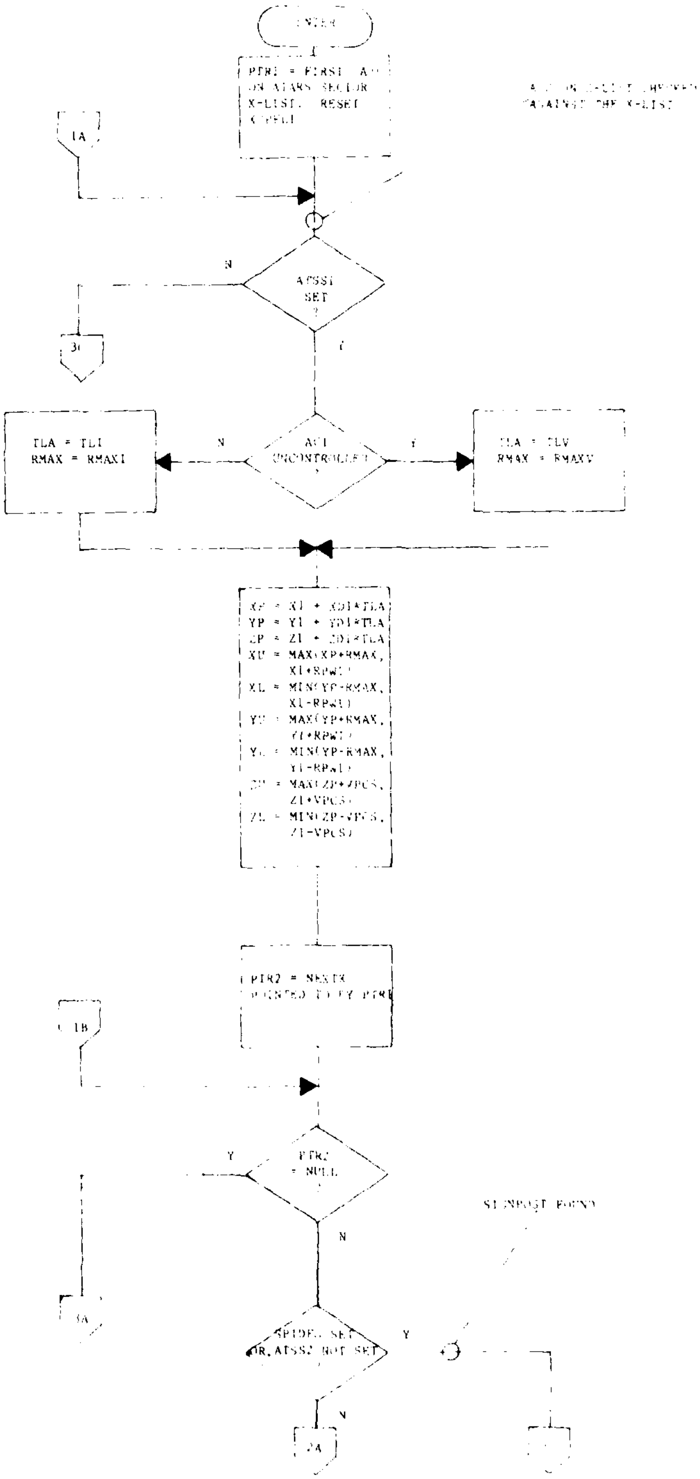


FIGURE 6-10
COARSE SCREEN PROCESSING TASK (Page 1 of 8)

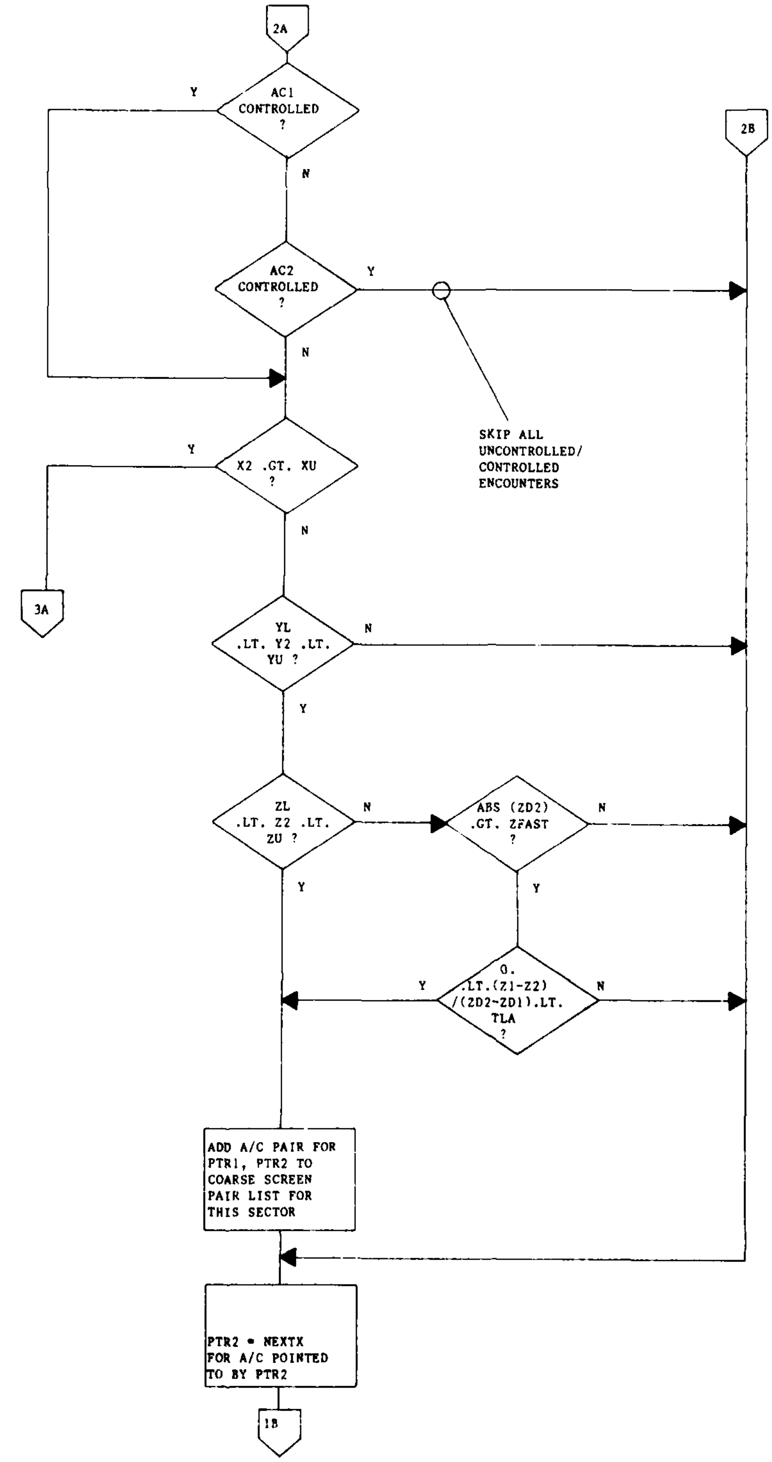


FIGURE 6-10
COARSE SCREEN PROCESSING TASK (Page 2 of 8)

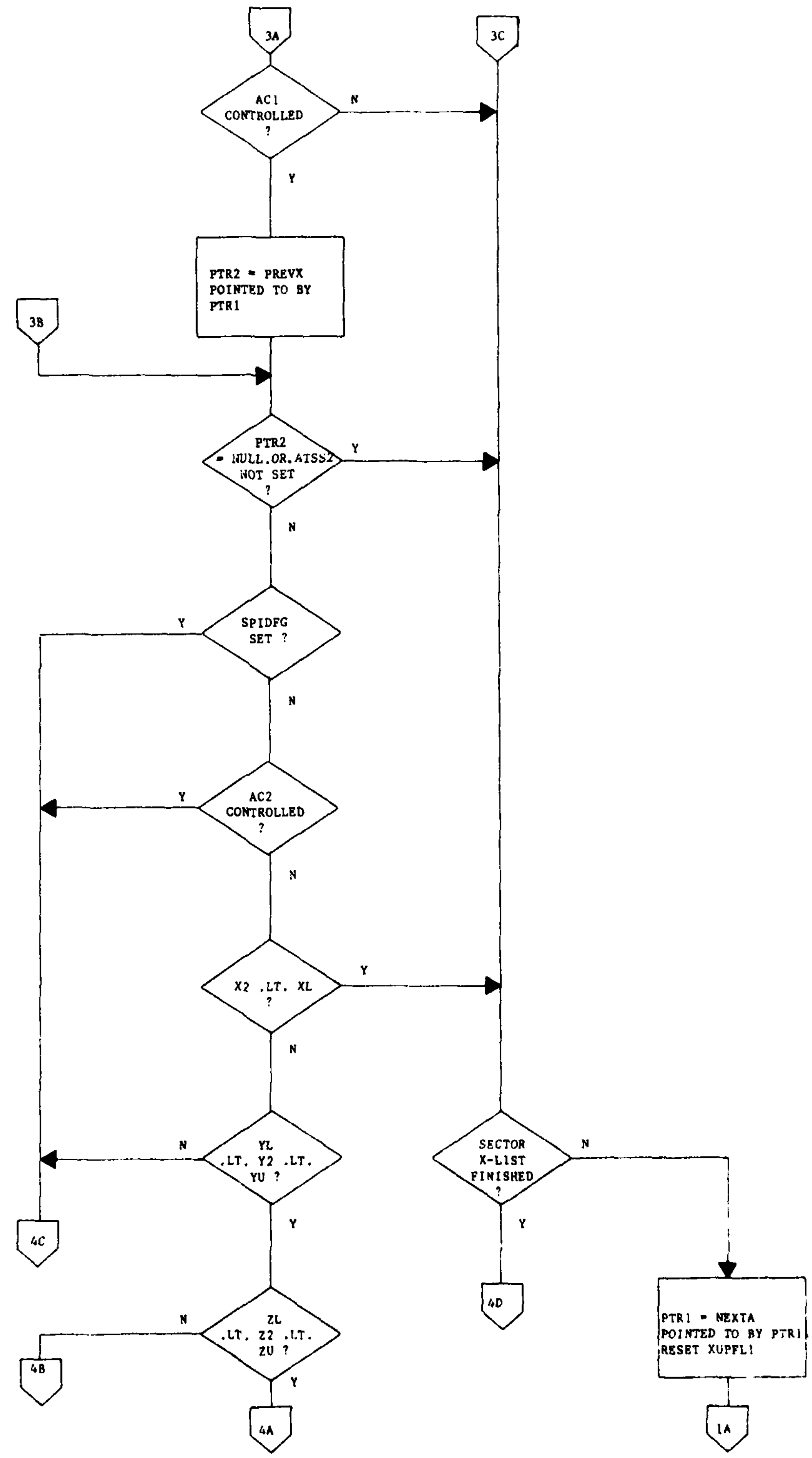


FIGURE 6-10
COARSE SCREEN PROCESSING TASK (Page 3 of 8)

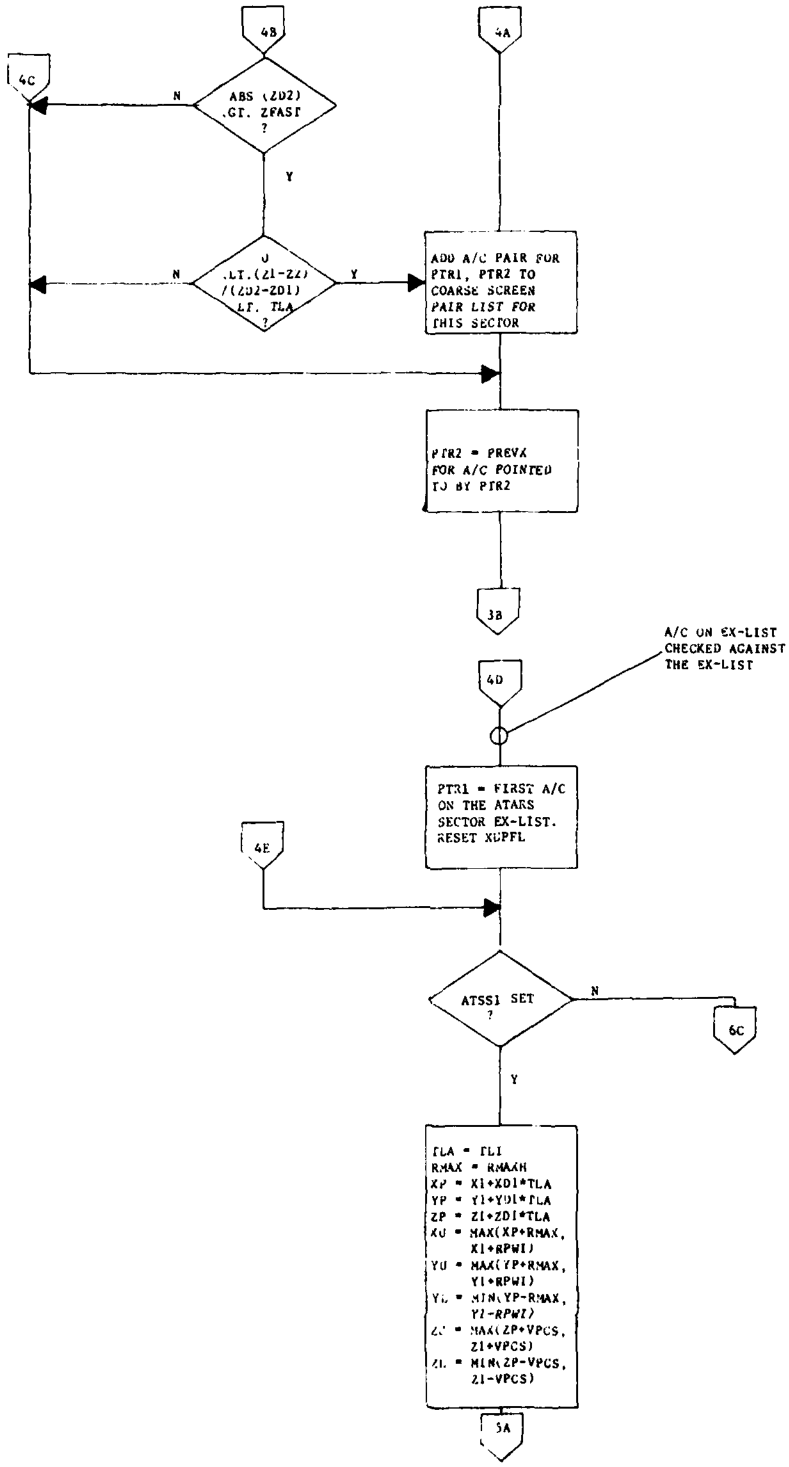


FIGURE 6-10
COARSE SCREEN PROCESSING TASK (Page 4 of 8)

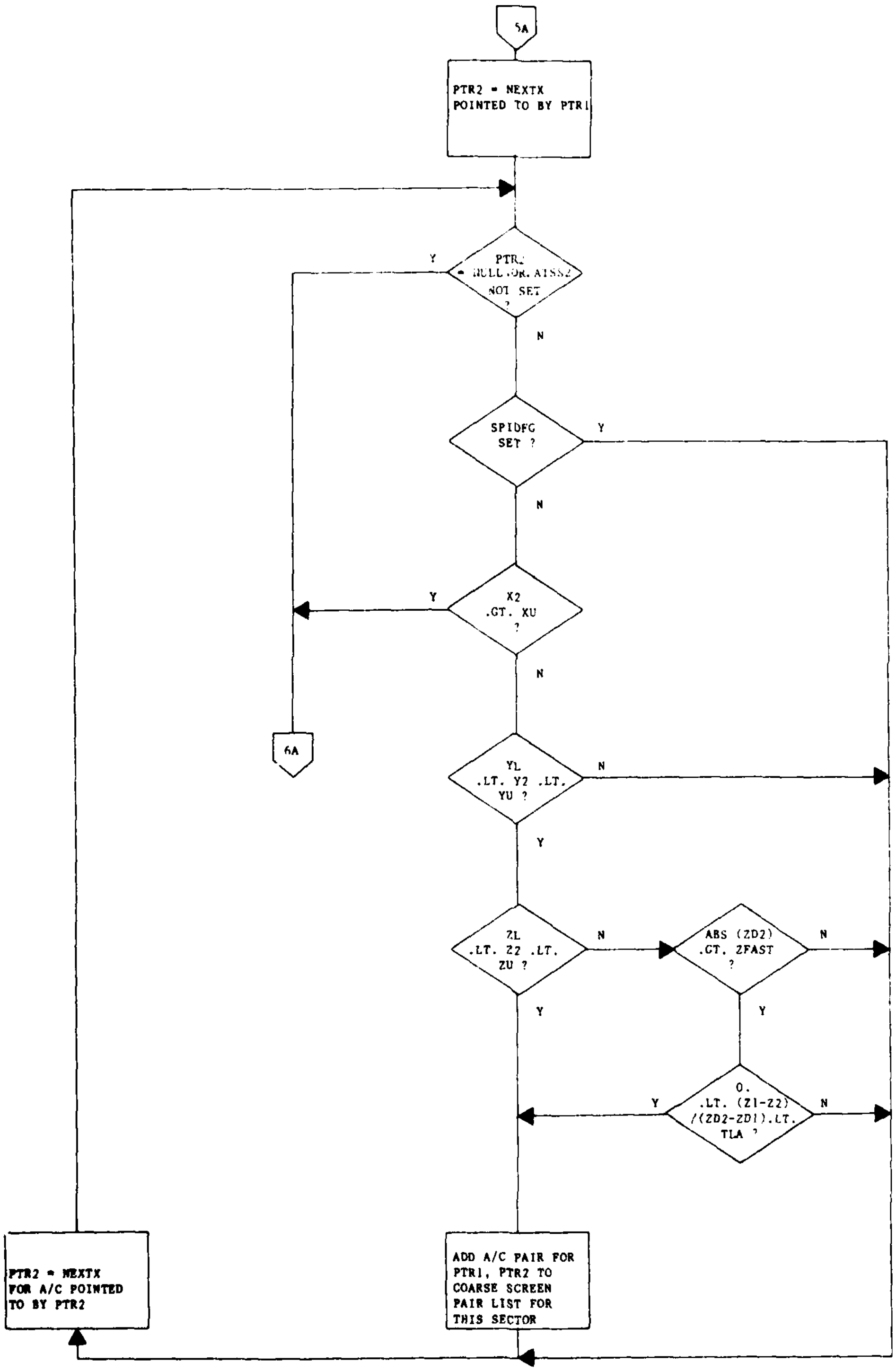


FIGURE 6-10
COARSE SCREEN PROCESSING TASK (Page 5 of 8)

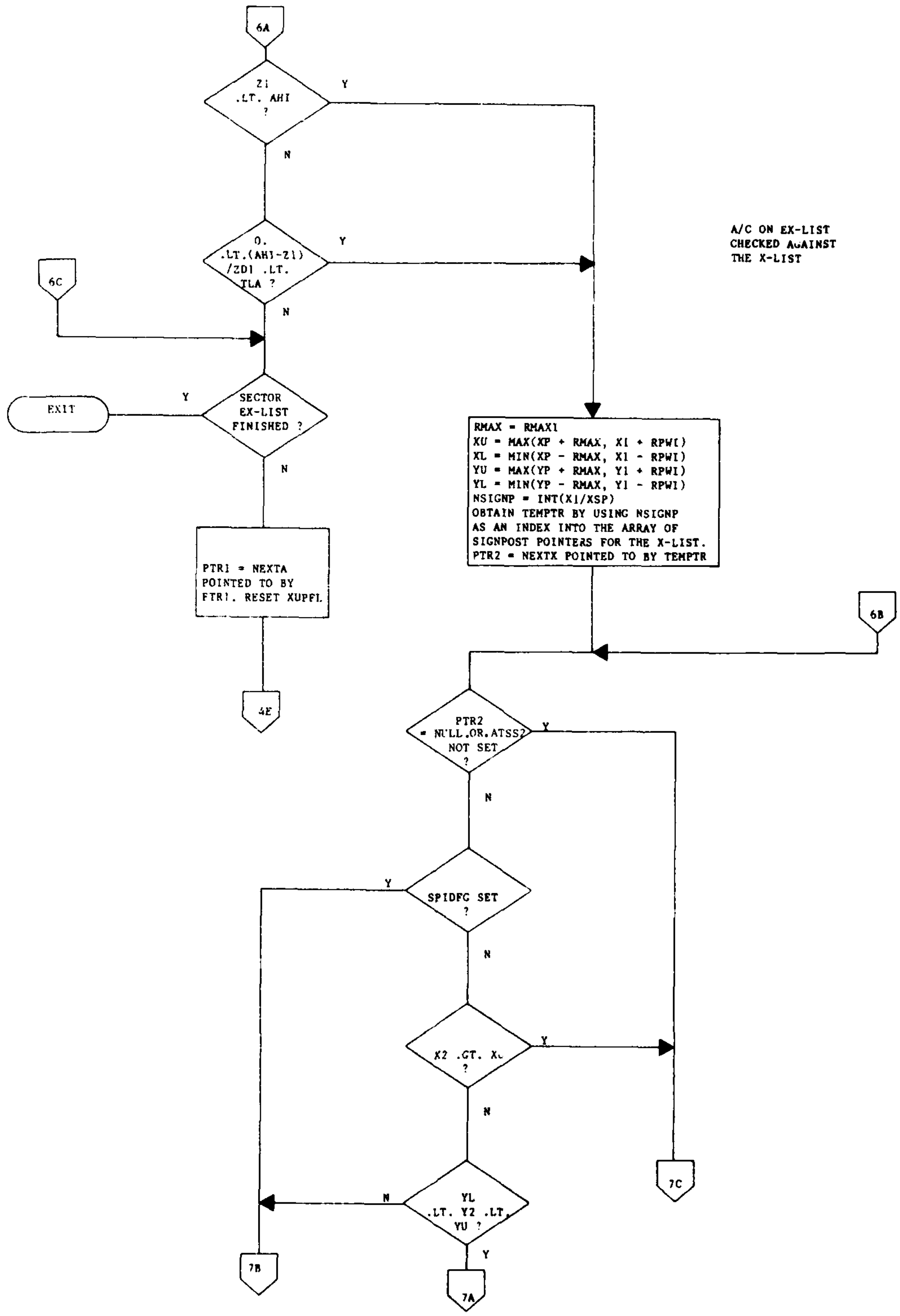


FIGURE 6-10
COARSE SCREEN PROCESSING TASK (Page 6 of 8)

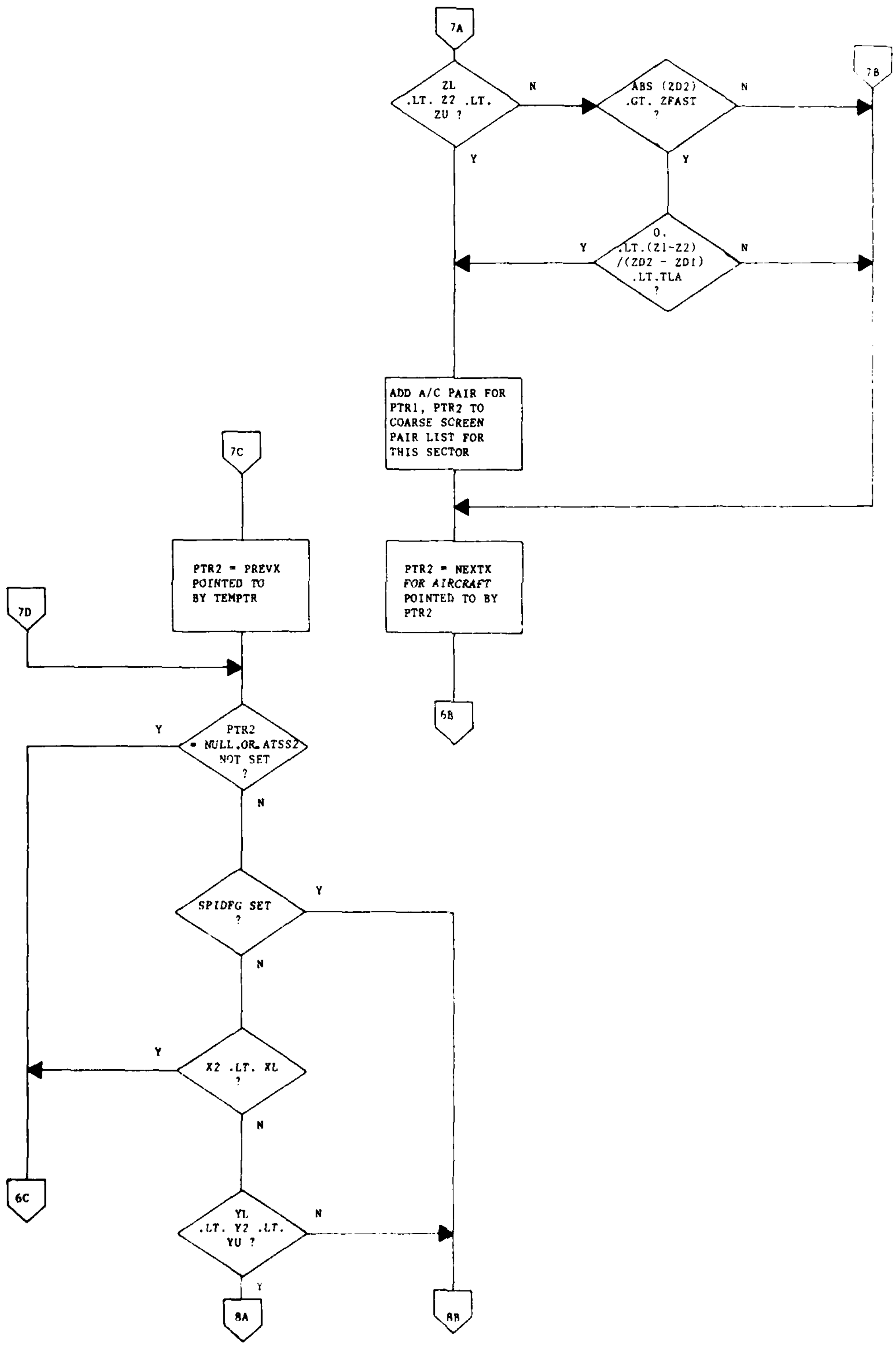


FIGURE 6-10
COARSE SCREEN PROCESSING TASK (Page 7 of 8)

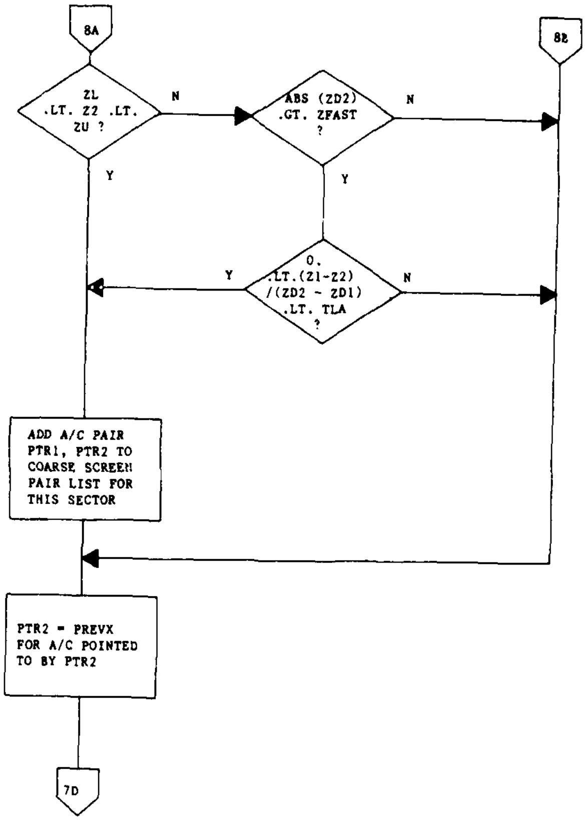


FIGURE 6-10
COARSE SCREEN PROCESSING TASK (Page 8 of 8)

TABLE 6-1

PARAMETERS USED IN COARSE SCREEN PROCESSING TASK FLOW CHART

SYMBOL	USE	NOMINAL VALUE
AHI	Altitude threshold for search of X-list with aircraft from EX-list.	12,000 ft
RMAX	Maximum distance traveled by an aircraft over the longest appropriate system look-ahead time.	---------
RMAXH	RMAX to be used for all searches on the EX-list.	20 nmi
RMAXI	RMAX to be used with a controlled subject aircraft.	8 nmi
RMAXV	RMAX to be used with an uncontrolled subject aircraft.	5 nmi
RPWI	Maximum separation between aircraft for a proximity advisory.	4 nmi
TLA	Largest appropriate look-ahead time.	---------
TLI	TLA to be used with a controlled subject aircraft.	120 sec
TLV	TLA to be used with an uncontrolled subject aircraft.	75 sec
VPCS	Vertical proximity test limit.	2,000 ft
XSP	Nominal signpost X distance.	5 nmi
ZFAST	Z velocity threshold for non-subject aircraft.	1,000 fpm

TABLE 6-2

VARIABLES USED IN COARSE SCREEN PROCESSING TASK FLOW CHART

SYMBOL	USE
XP, YP, ZP	Projected location of aircraft after longest appropriate look-ahead time (TLA).
XL, XU	Lower and upper X search limits.
YL, YU	Lower and upper Y search limits.
ZL, ZU	Lower and upper Z search limits.
NULL	The null pointer.

to be checked against those marked in the X/EX-lists. For all aircraft encountered in these searches, the Y and Z limit tests and the Z rate limit test are applied. If these tests show a possible conflict, then a pair of aircraft which requires further processing has been identified. This pair of aircraft is entered on the Coarse Screen Pair List for the this sector.

Any individual aircraft is included on only the X-list or EX-list. Hence, when an aircraft on the EX-list must be tested against aircraft on the X-list, special provisions must be made for finding the place on the X-list to begin the search. A procedure analogous to that used for initial entry on the X-list is used in which the first signpost below the aircraft's X position is obtained and the X-list entered at that point. It is not important to locate the subject aircraft's exact position on the X-list; it is sufficient to obtain an entry point between the upper and lower limits. If the distance between signposts is small enough, this will happen automatically. Even if an entry point to the X-list were used, which fell outside the X-limits, the procedure would work correctly but would be inefficient since more aircraft than necessary would be tested in coarse screening.

6.6 Terrain/Airspace/Obstacle Avoidance

The capability to provide an alert for the violation of restricted airspace, close proximity to the terrain, and close proximity to an obstacle is provided by this task. This task requires an ordered X-list before it can operate on the sector of aircraft under consideration. The logic to determine the need for an alert is provided here while the actual construction of the message is performed by the Data Link Message Construction Task. The Terrain/Airspace/Obstacle Avoidance Task is presented in Figure 6-11. Only aircraft which are in the ATARS service area are eligible for processing.

6.6.1 Terrain Avoidance Processing

The Terrain Avoidance Routine is described in Figure 6-12. The Mode C barometric pressure correction is provided with the surveillance report. Aircraft which are on final approach will be below the terrain altitude threshold for the final phase of flight. Therefore, a special check is required to inhibit alerts if aircraft are on the final approach glide slope.

The real time processing of the map of the terrain is similar to the method used in the Terminal Area Minimum Safe Altitude

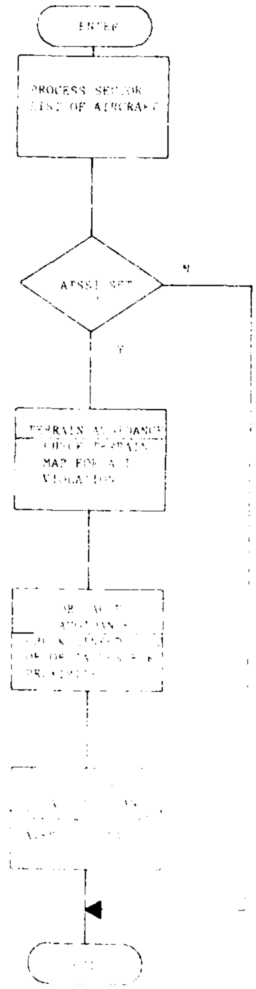
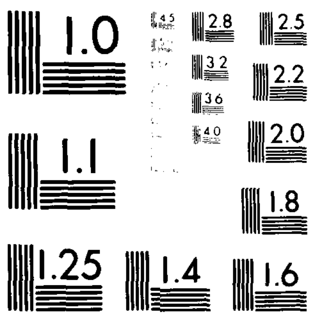


FIGURE 6-11
TERRAIN/AIRSPACE/OBSTACLE AVOIDANCE TASK

AD-A094 195 MITRE CORP MCLEAN VA METREK DIV F/G 1/5
AUTOMATIC TRAFFIC ADVISORY AND RESOLUTION SERVICE (ATARS) MULTI--ETC(U)
OCT 80 R H LENTZ, W D LOVE, N S MALTHOUSE DOT-FA80WA-4370
UNCLASSIFIED MTR-80W00100-REV-1 FAA-RD-80-3-REV-1 NL

3 of 6
AD A
094195



MICROCOPY RESOLUTION TEST CHART

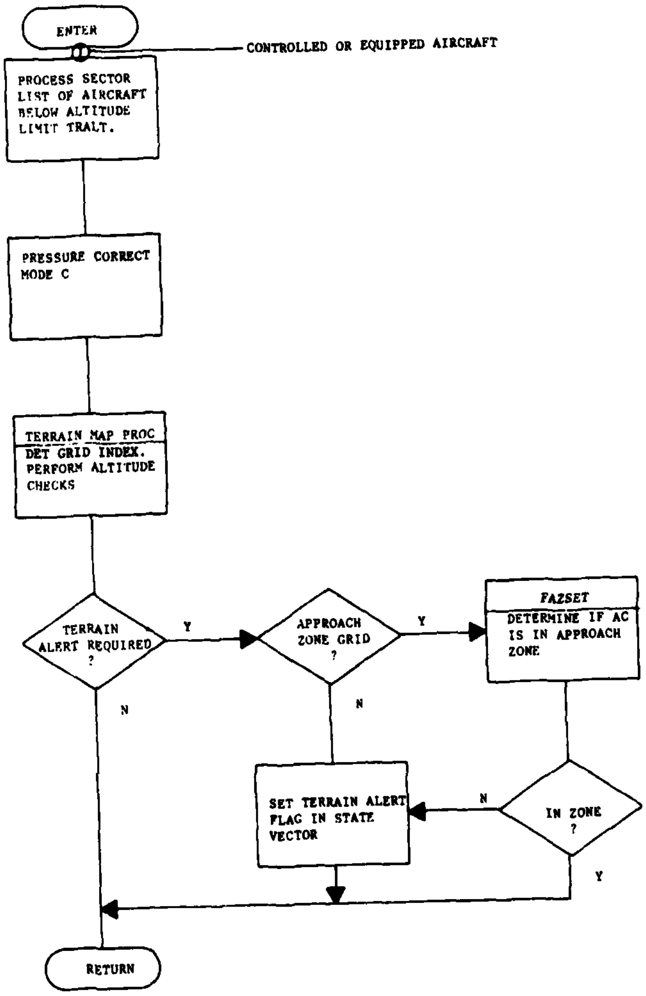


FIGURE 6-12
TERRAIN AVOIDANCE ROUTINE

Warning (MSAW) function described in Reference 7. A major difference concerns the use of a grid map with variable bin sizes and the associated indexing required to access the altitude threshold for each high level and sub-level terrain bin. Figure 6-13 presents the logic to access the terrain map, project (horizontally) the aircraft, determine the bin altitude threshold, and compare the threshold to the aircraft altitude. Figure 6-14 gives an example of the bins to be checked. Table 6-3 summarizes the altitude checks required for each event in the projection of the aircraft.

The off-line generation of the terrain map is described in Figure 6-15. This procedure is identical to the method used in Reference 7 with the exception of the sub-level indexing and the marking of bins which are in a final approach zone. A data structure implementation for the terrain map is presented in Figure 6-16.

6.6.2 Obstacle Avoidance Processing

Figure 6-17 presents the routine for obstacle avoidance processing. This logic is only applied to aircraft which are below a minimum altitude. An X-ordered linked list of obstacles is generated off-line and stored for access by the Obstacle Avoidance Routine. This list will contain position and altitude information for each obstacle. Proximity to an obstacle is determined by adding an X, Y, Z system parameter to the position data in the direction of the velocities of the respective data. A check for convergence with the obstacle is made before issuing an alert.

6.6.3 Restricted Airspace Avoidance Processing

The Restricted Airspace Avoidance Routine is presented in Figure 6-18. This logic consists of two major elements, 1) providing an advisory to uncontrolled aircraft upon first entry into a Terminal Control Area (TCA) and, 2) providing on alert to any aircraft which has entered an area of restricted airspace. The technique for storage and access of the TCA map should allow effective use of the ATARS processors. The storage of the restricted airspace areas and the logical checks for determining if an aircraft is inside an area is the same as that described for processing of airport area types (see Section 7.1.4).

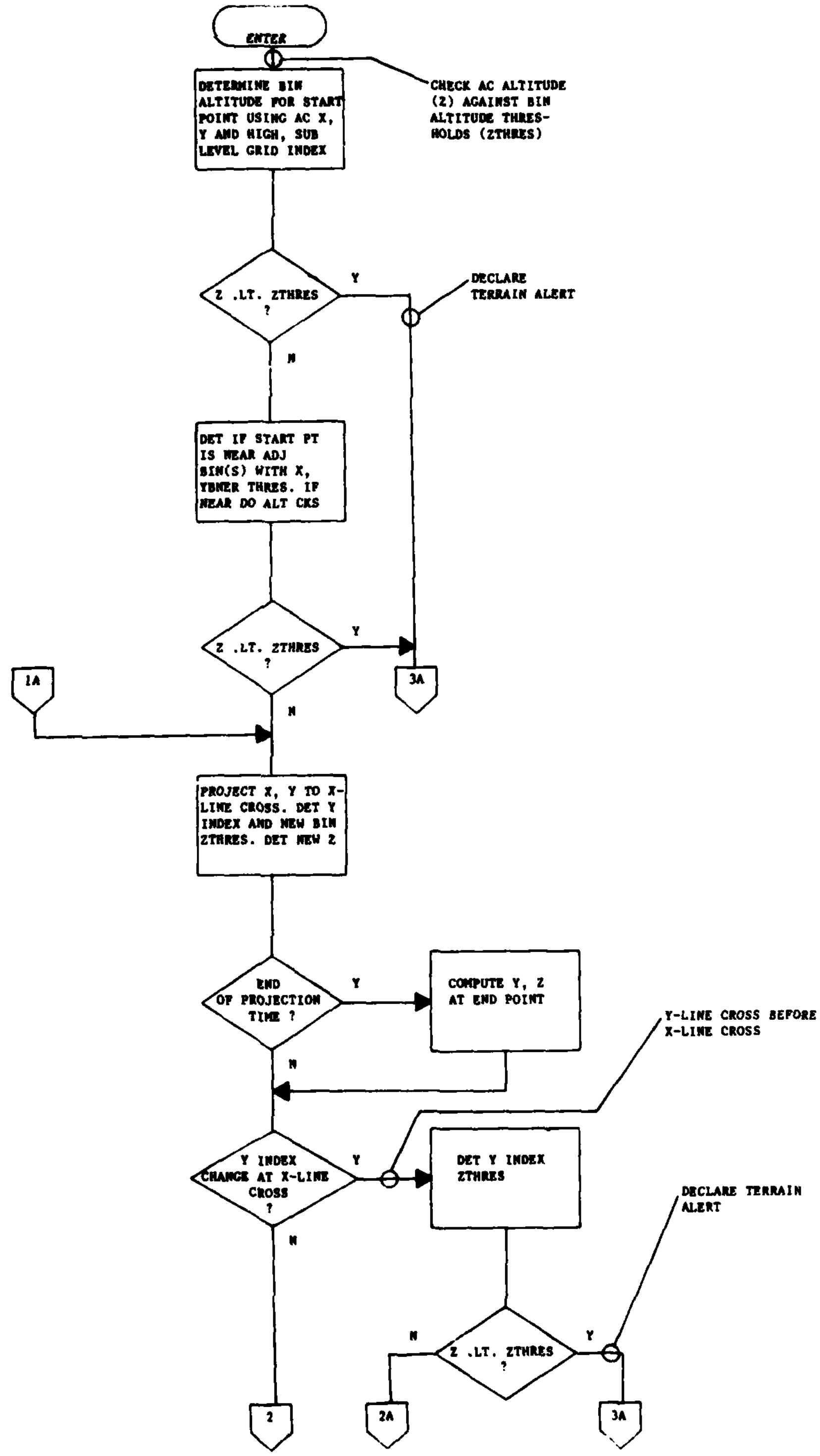


FIGURE 6-13
TERRAIN MAP PROCESSING ROUTINE (Page 1 of 3)

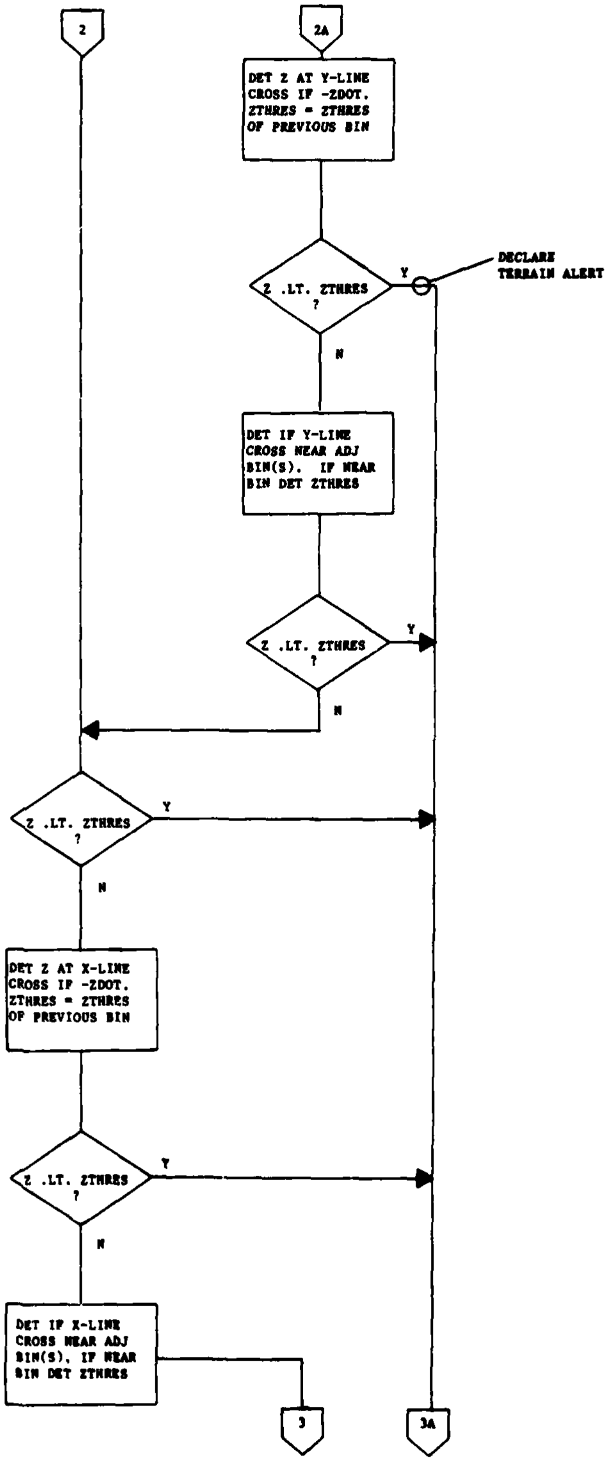


FIGURE 6-13
TERRAIN MAP PROCESSING ROUTINE (Page 2 of 3)

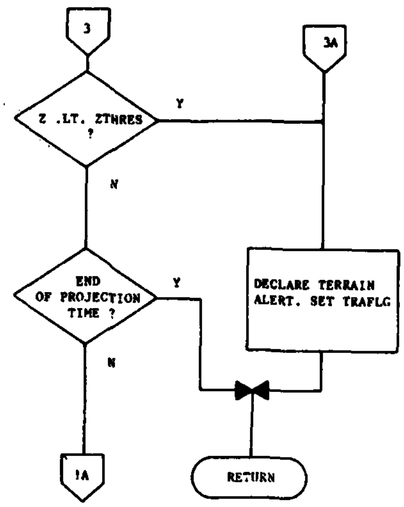
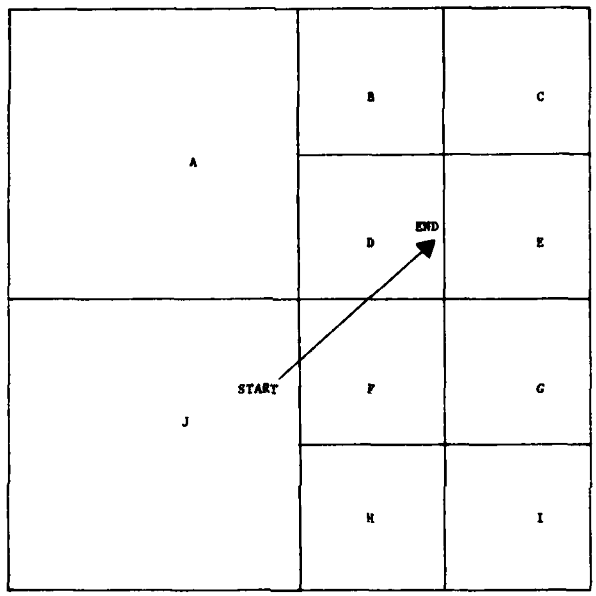


FIGURE 6-13
TERRRAIN MAP PROCESSING ROUTINE (Page 3 of 3)



ALTITUDE THRESHOLDS WHICH ARE CHECKED:
J, A, F, D, E. (NO CHECK ON G BECAUSE
END POINT TOO FAR AWAY.

FIGURE 6-14
BIN CHECK EXAMPLE

TABLE 6-3

TERRAIN ALTITUDE CHECKS

Event	Altitude Checks Check Aircraft Z Against
Start or End of Projection Point	1. Current bin Z threshold 2. Adjacent bin(s) Z threshold
X-line cross point	1. New bin Z threshold 2. If negative ZDOT: Z threshold of previous bin (use aircraft Z at X-line cross point) 3. Adjacent bin(s) Z threshold
Y-line cross point	1. New bin Z threshold 2. If negative ZDOT: Z threshold of previous bin (use aircraft Z at Y-line cross point) 3. Adjacent bin(s) Z threshold

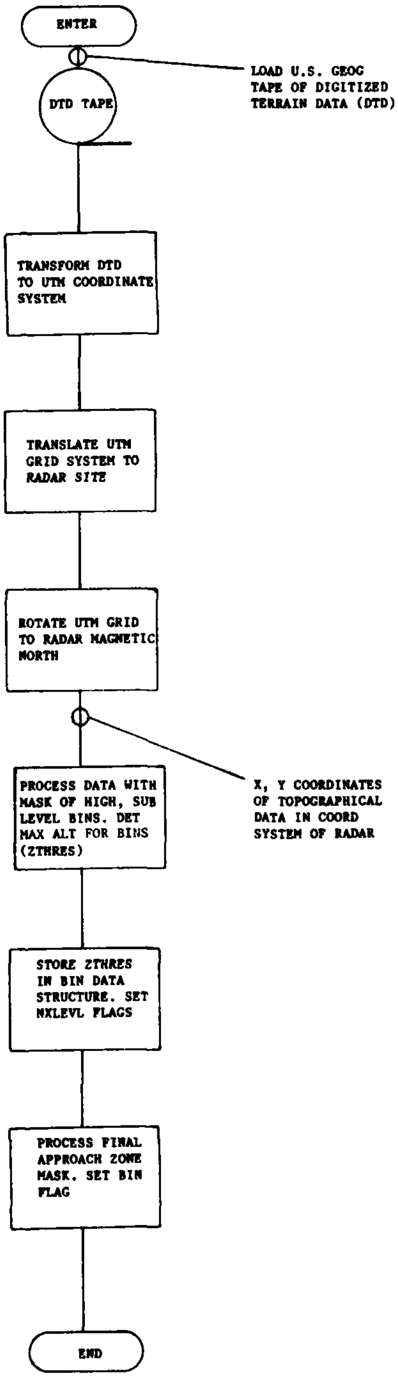


FIGURE 6-15
DESCRIPTION OF TERRAIN MAP GENERATION

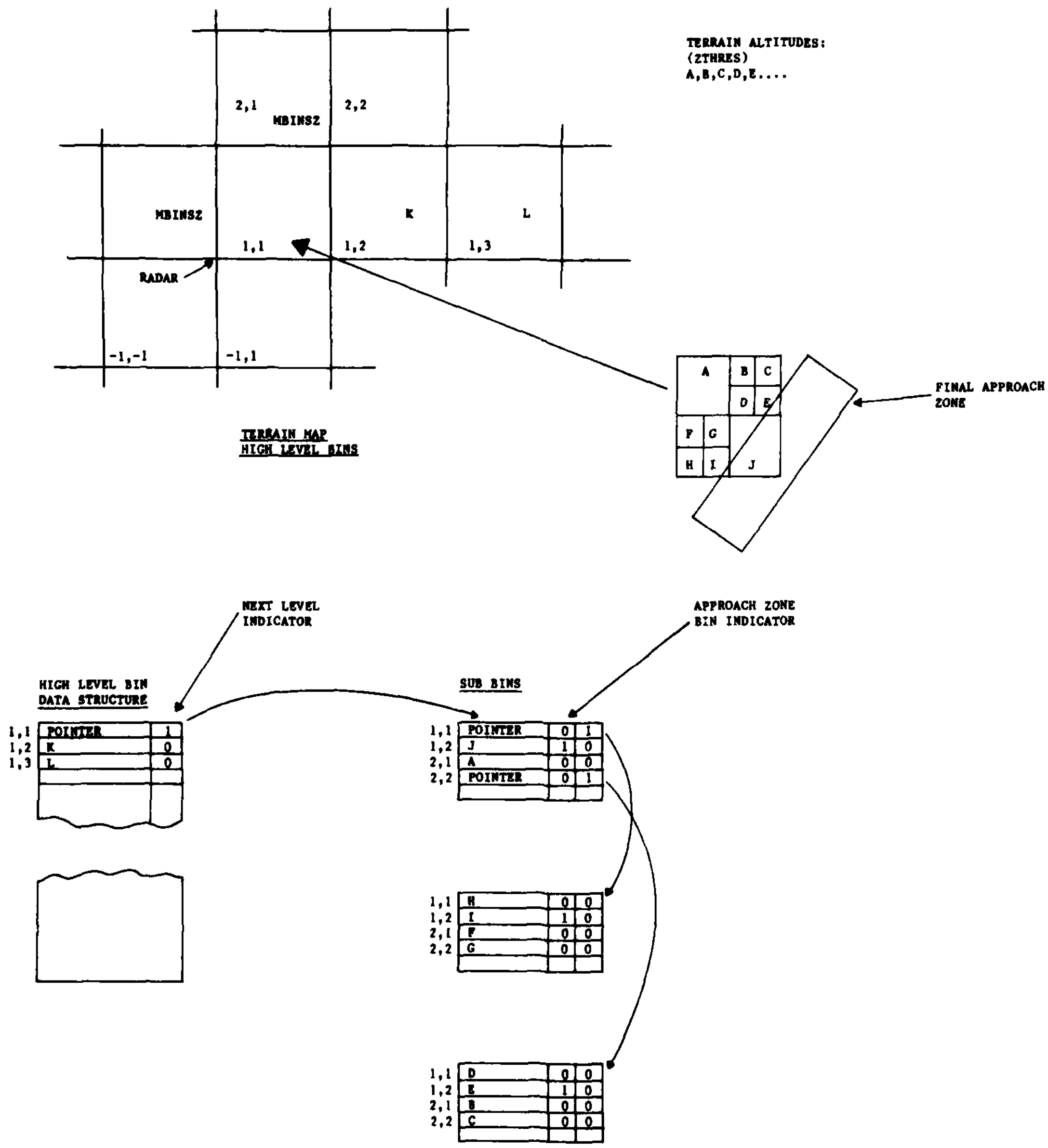


FIGURE 6-16
TERRAIN MAP DATA STRUCTURE

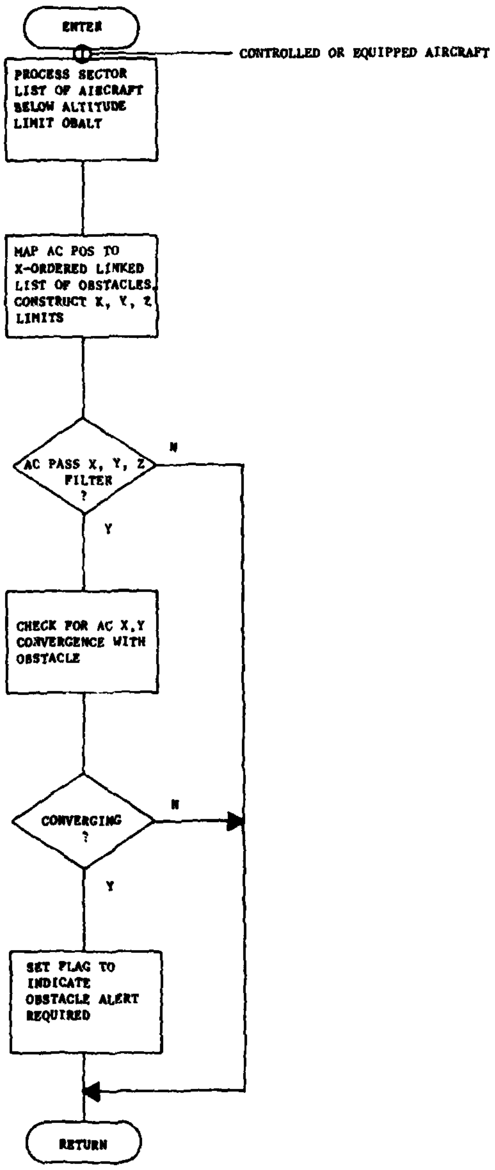


FIGURE 6-17
OBSTACLE AVOIDANCE ROUTINE

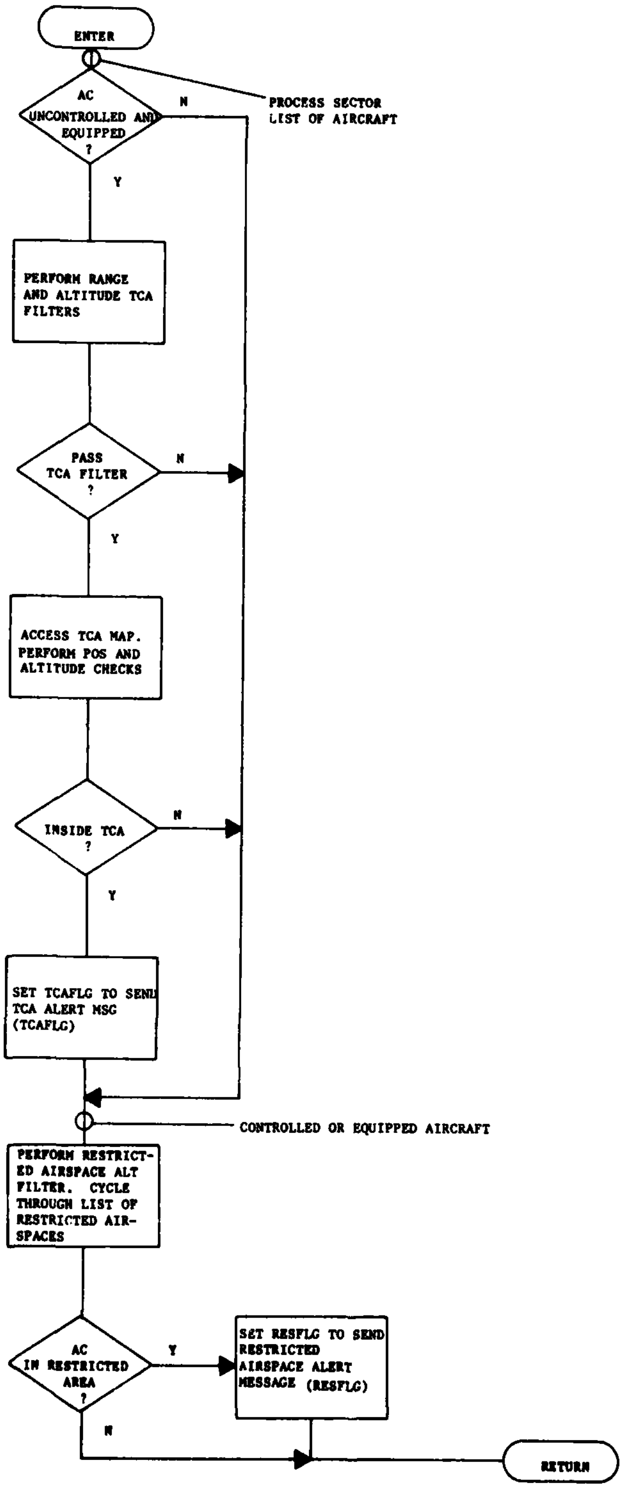


FIGURE 6-18
RESTRICTED AIRSPACE AVOIDANCE ROUTINE

7. CONFLICT PAIR DETERMINATION AND DISPOSITION

Two tasks are discussed in this section, the Detect Task and the Seam Pair Task. These functions are to examine screened aircraft pairs for potential conflict situations and to determine the type of subsequent ATARS processing. The Detect Task determines if an aircraft pair requires further ATARS action (controller alert, proximity, threat or resolution advisory), while the Seam Pair Task determines which ATARS site has responsibility for the pair, the file disposition of the pair and consequently the type of further ATARS processing.

The main body of the succeeding pages of Section 7 are tables and figures. It is intended that a study of these charts alone will impart all that is necessary to know the specifications of the two tasks mentioned, with the text serving a supporting role. As such, a description of the organization of charts and figures is pertinent.

Figure 7-1 is a descriptive flow chart of the main elements of the Detect Task. Figure 7-2 gives the specifications of the Detect Task on a programmable level. The following Figures, 7-3 through 7-15, are flow charts of all supporting routines referenced in Figure 7-2 by a process block containing the routine name underlined. The remaining figure, 7-16, is the flow chart for the Seam Pair Task. Table 7-1 through 7-3 relate (1) equipage and control state of an aircraft with the possible flag settings that are the primary output of the detection function, (2) these flags with the routine that determines them and (3) the routines called depending on an aircraft pair state. A study of these tables will help in explaining the decision diamonds in the preceding flow charts. Tables 7-4 through 7-12 state recommended system parameter values for variables referenced in the flow charts. Table 7-11 summarizes all such parameters and the routines which utilize them. The last table, 7-12, specifies the information needed for further processing of the conflict pair after the Detect Task is complete. The trailing text is a summary of the two tasks, Detect and Seam Pair. The reader who desires an overview should examine the text; Tables 7-1, 7-2, 7-3; Figures 7-1, 7-16; and possibly Figure 7-2.

7.1 Detection

The Detect Task, given a pair of aircraft, their position, velocity, flight status and equipage, determines:

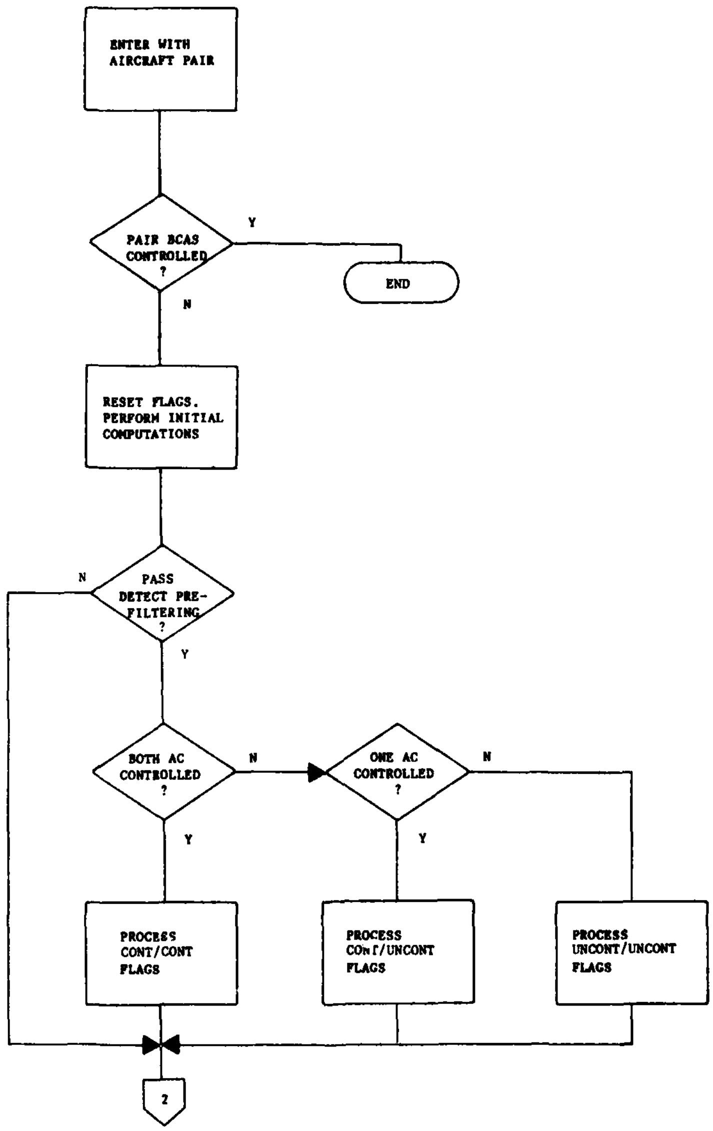


FIGURE 7-1
DESCRIPTION OF DETECT TASK (Page 1 of 2)

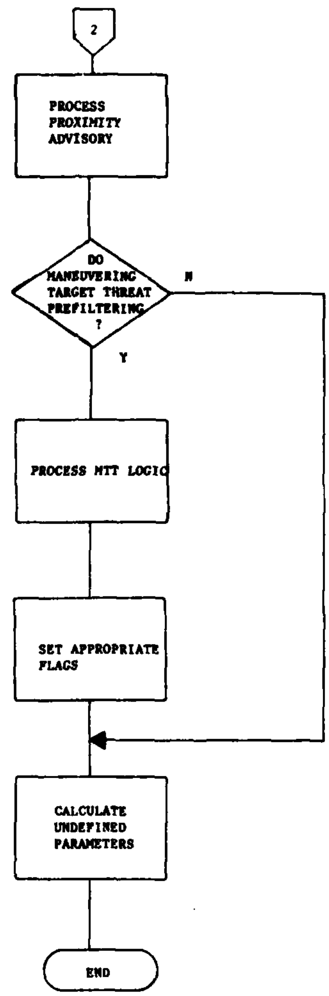


FIGURE 7-1
DESCRIPTION OF DETECT TASK (Page 2 of 2)

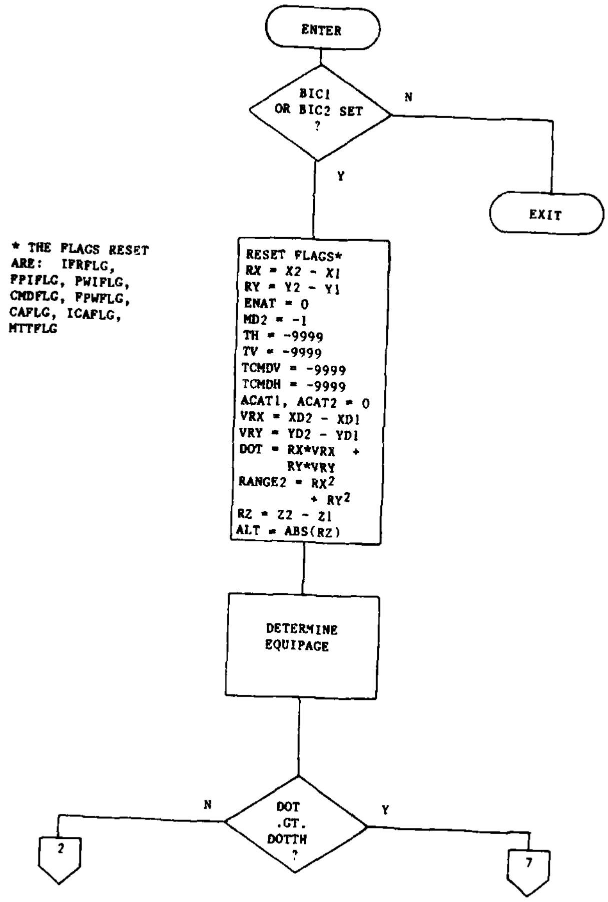


FIGURE 7-2
DETECT TASK (Page 1 of 9)

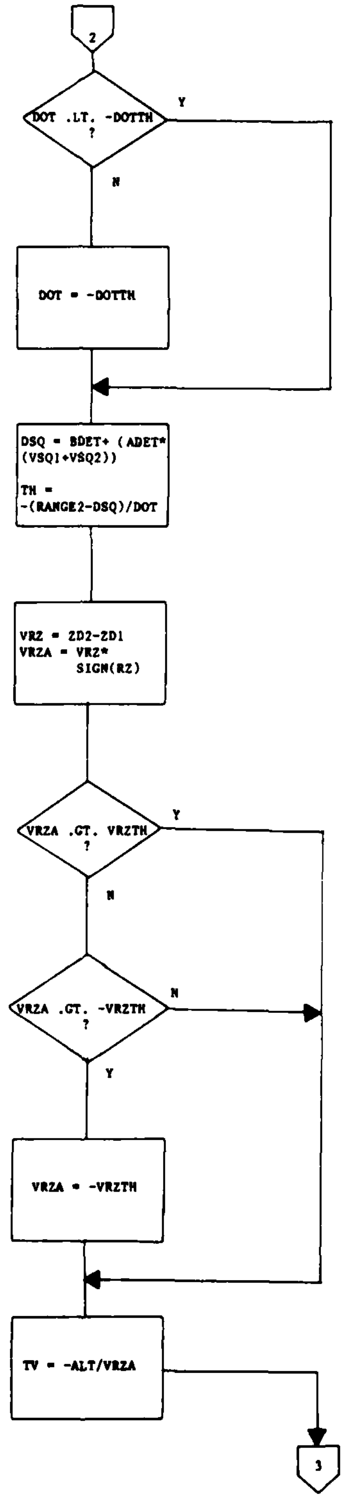


FIGURE 7-2
DETECT TASK (Page 2 of 9)

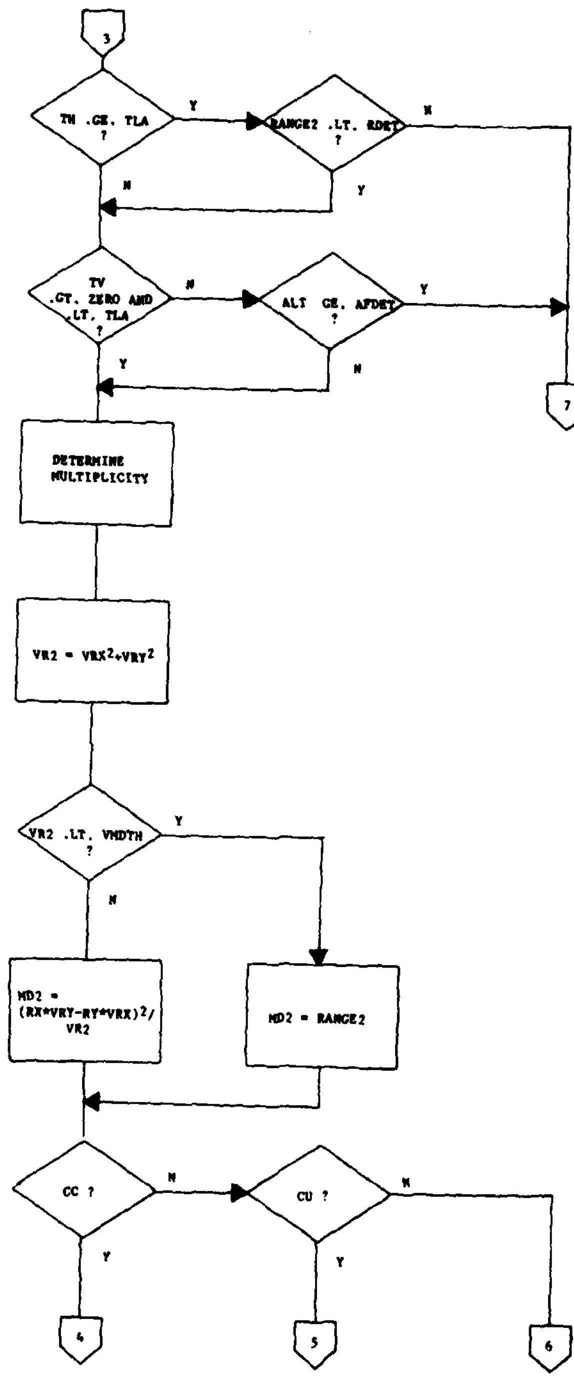


FIGURE 7-2
DETECT TASK (Page 3 of 8)

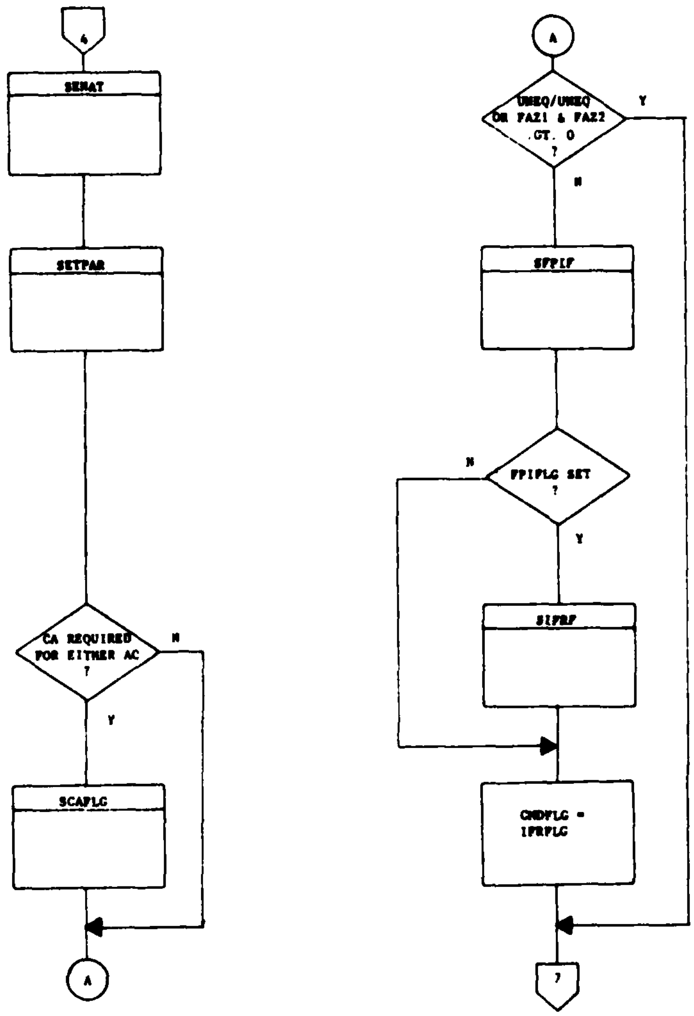


FIGURE 7-2
DETECT TASK (Page 4 of 9)

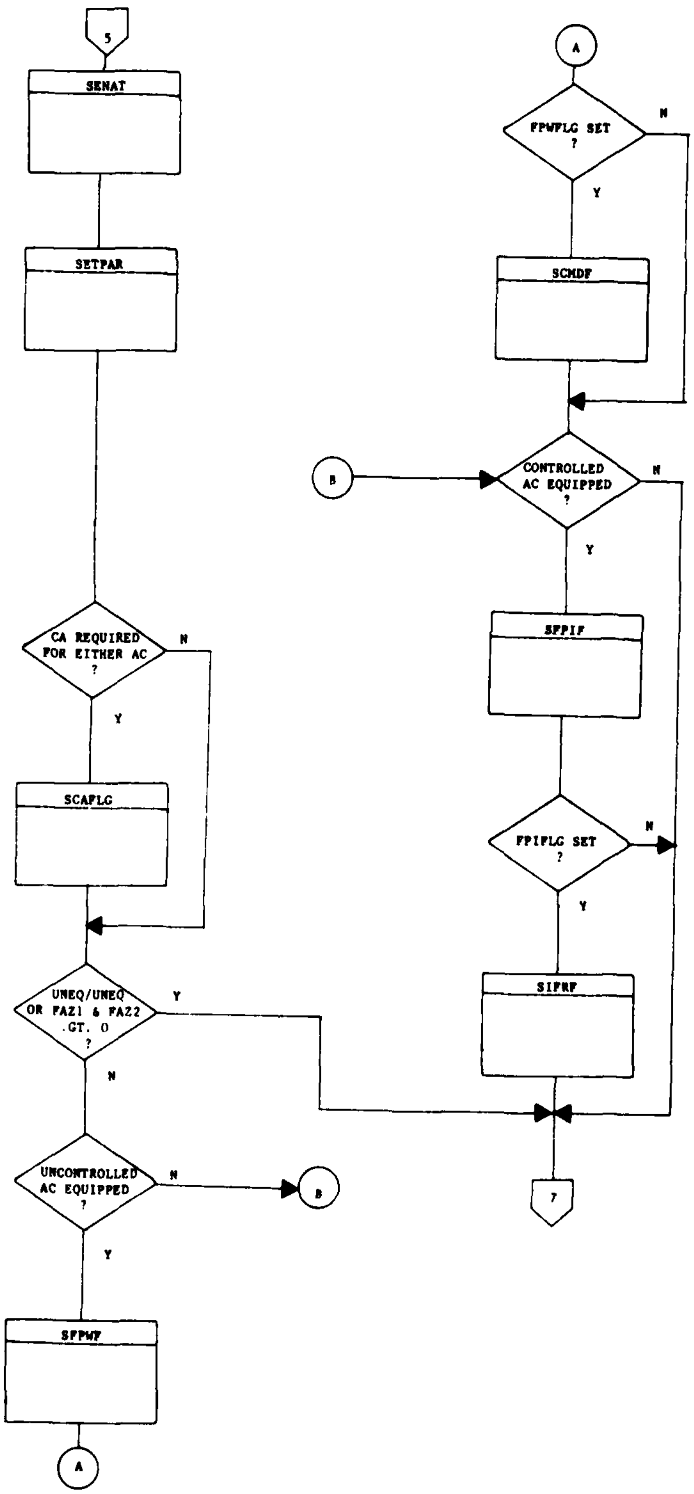


FIGURE 7-2
DETECT TASK (Page 5 of 9)

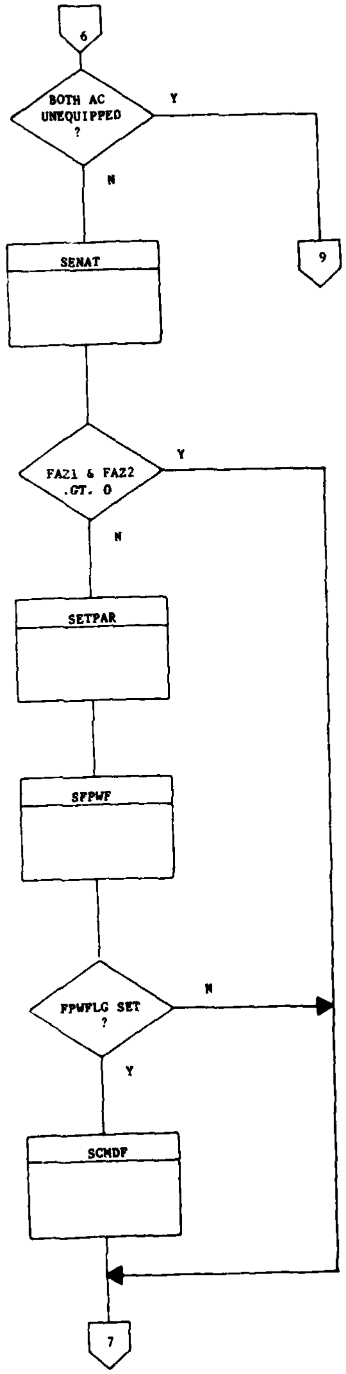


FIGURE 7-2
DETECT TASK (Page 6 of 9)

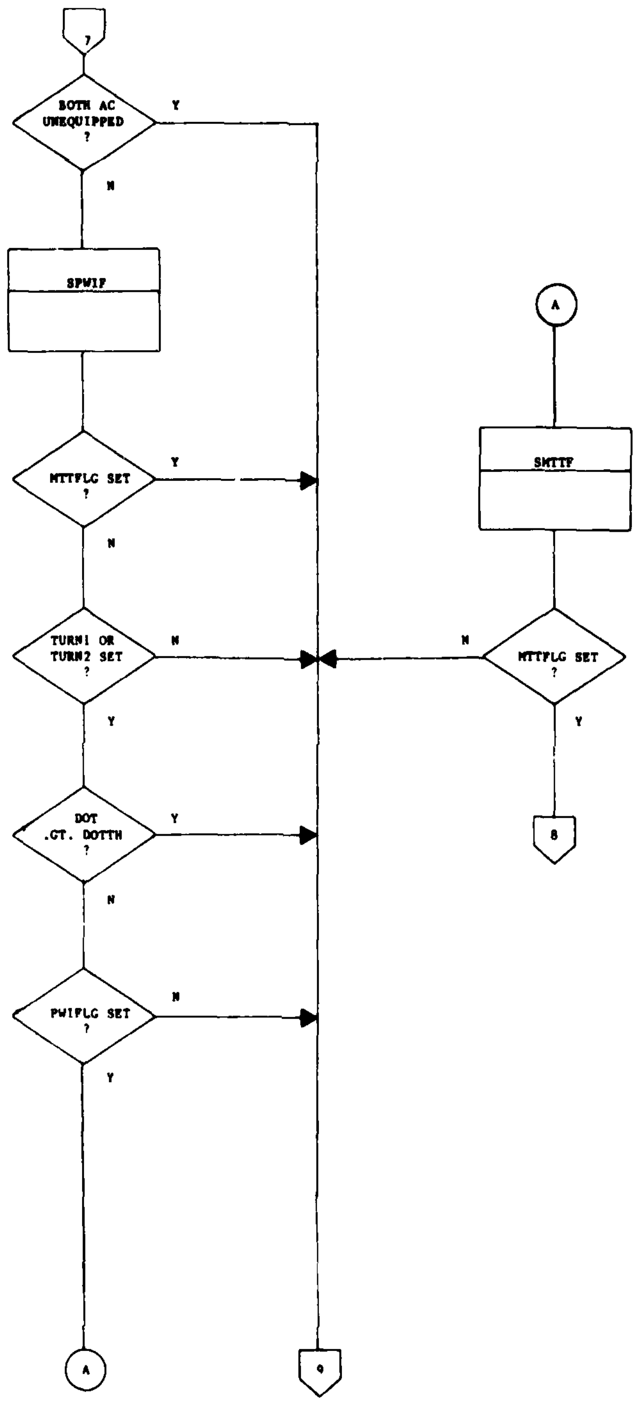


FIGURE 7-2
DETECT TASK (Page 7 of 9)

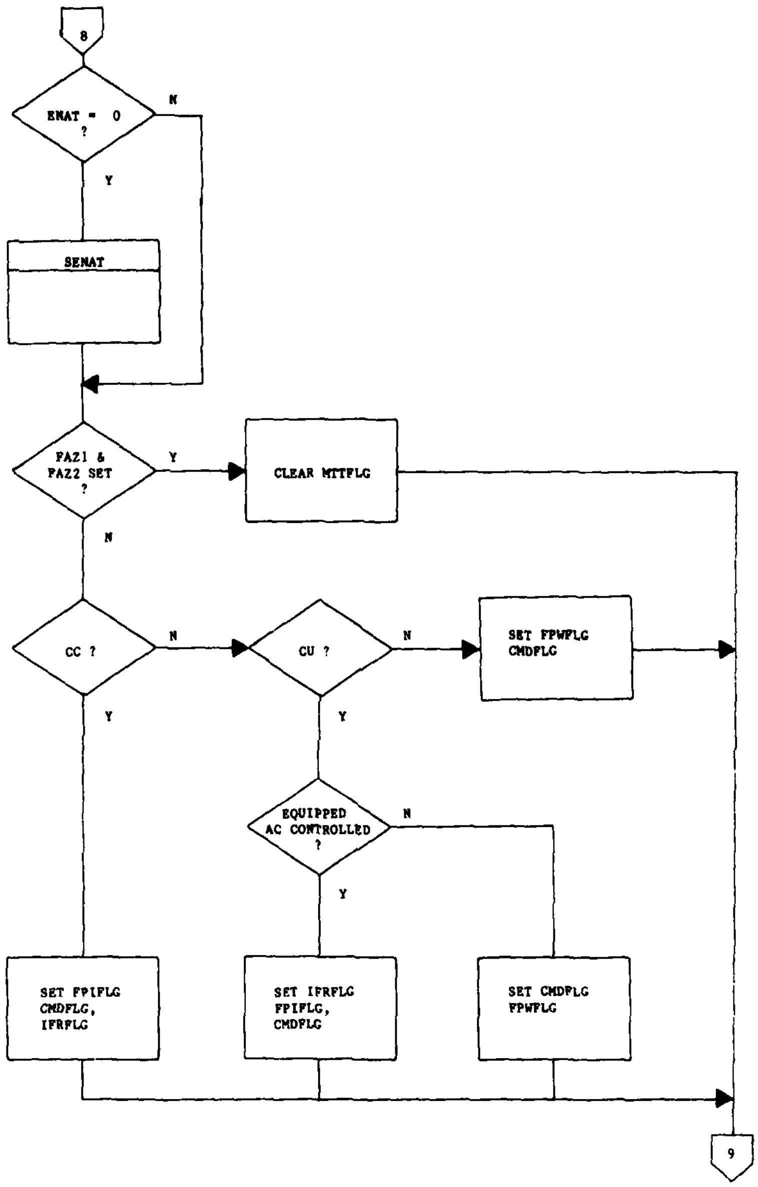


FIGURE 7-2
DETECT TASK (Page 8 of 9)

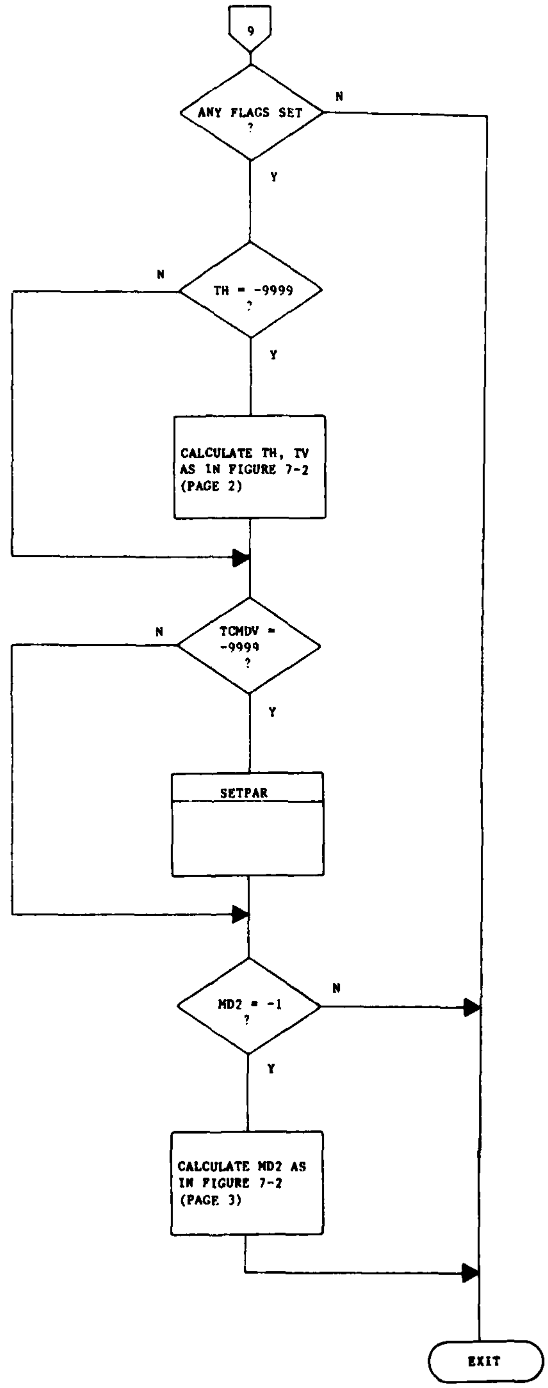


FIGURE 7-2
DETECT TASK (Page 9 of 9)

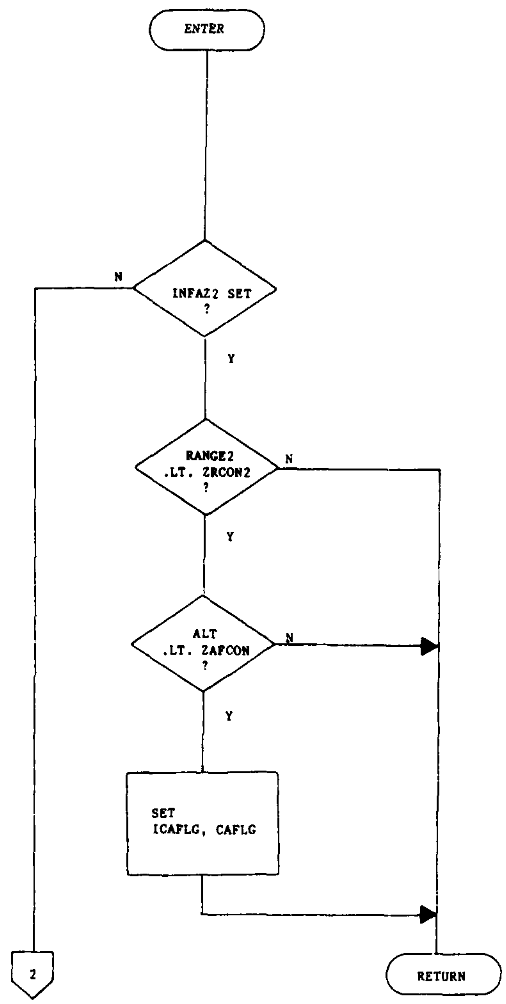


FIGURE 7-3
SCAFLG ROUTINE (Page 1 of 2)

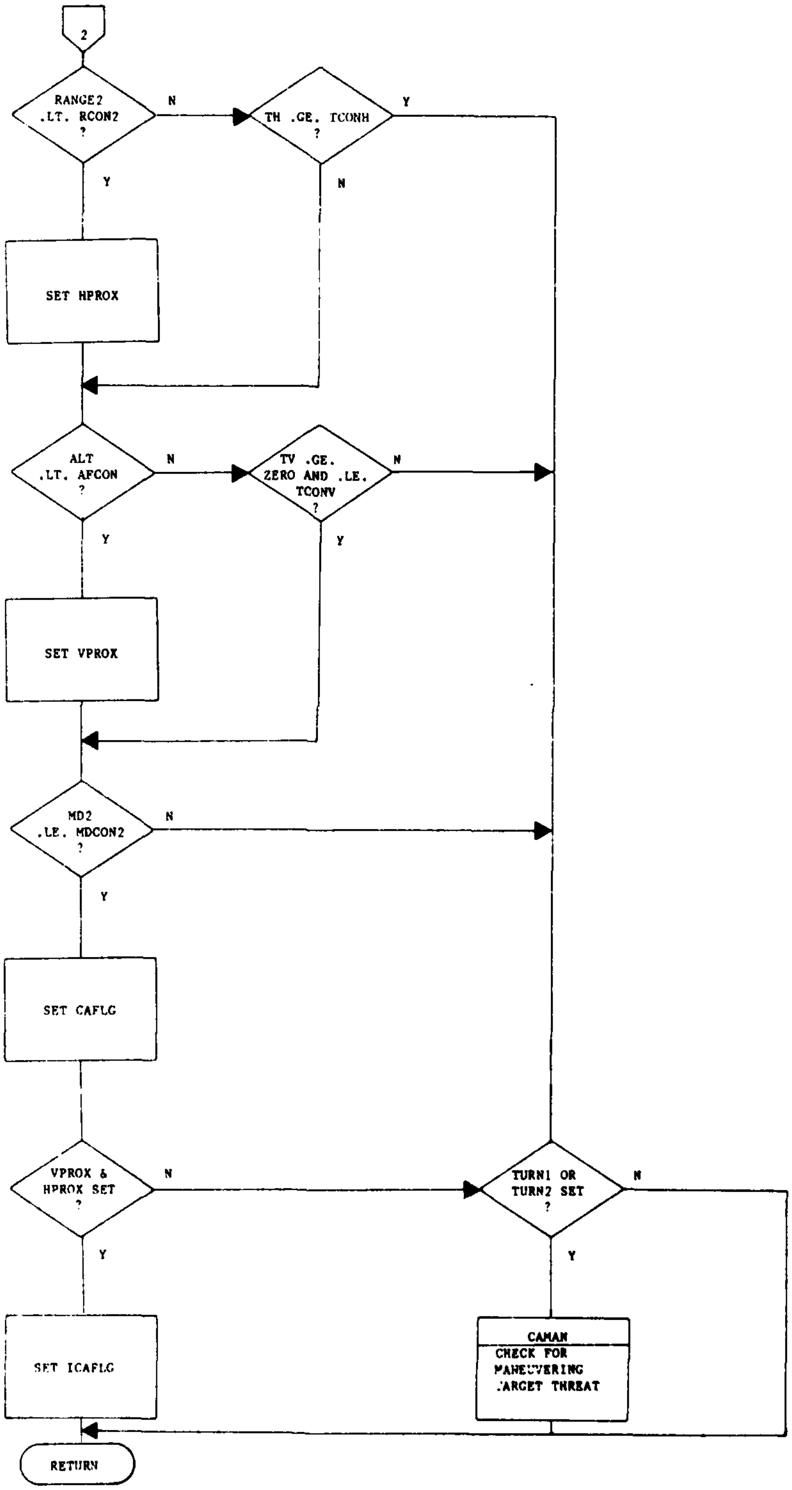


FIGURE 7-3
SCAFLG ROUTINE (Page 2 of 2)

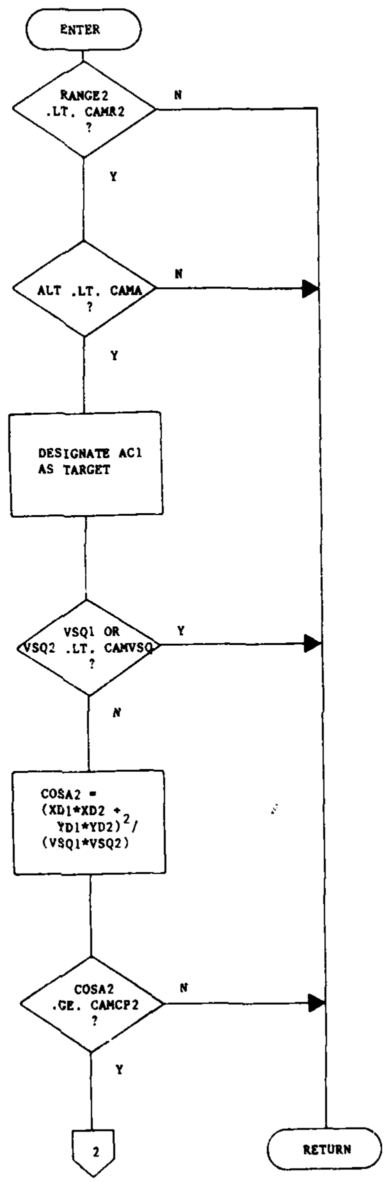


FIGURE 7-4
CAMAN ROUTINE (Page 1 of 2)

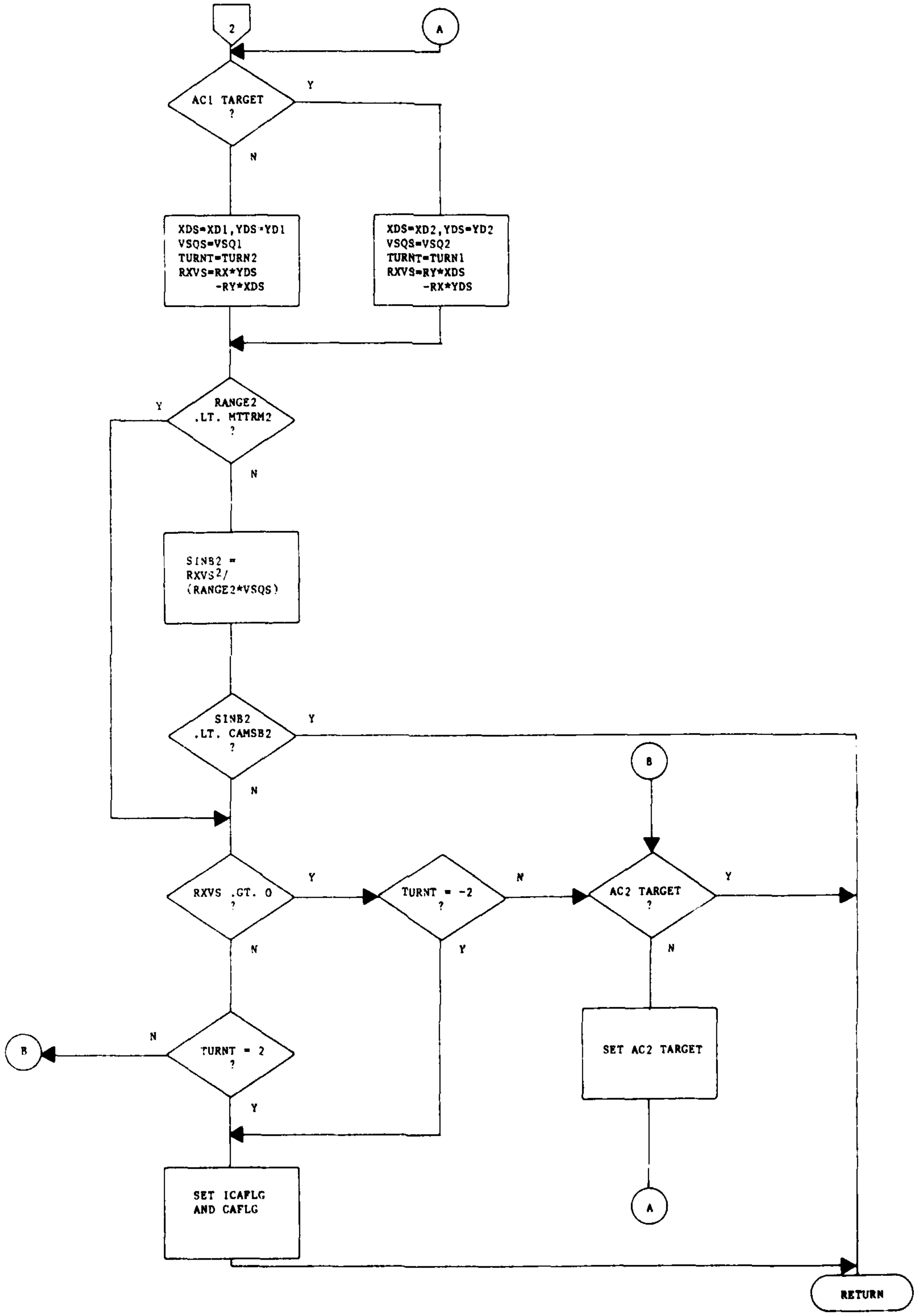


FIGURE 7-4
CAMAN ROUTINE (Page 2 of 2)

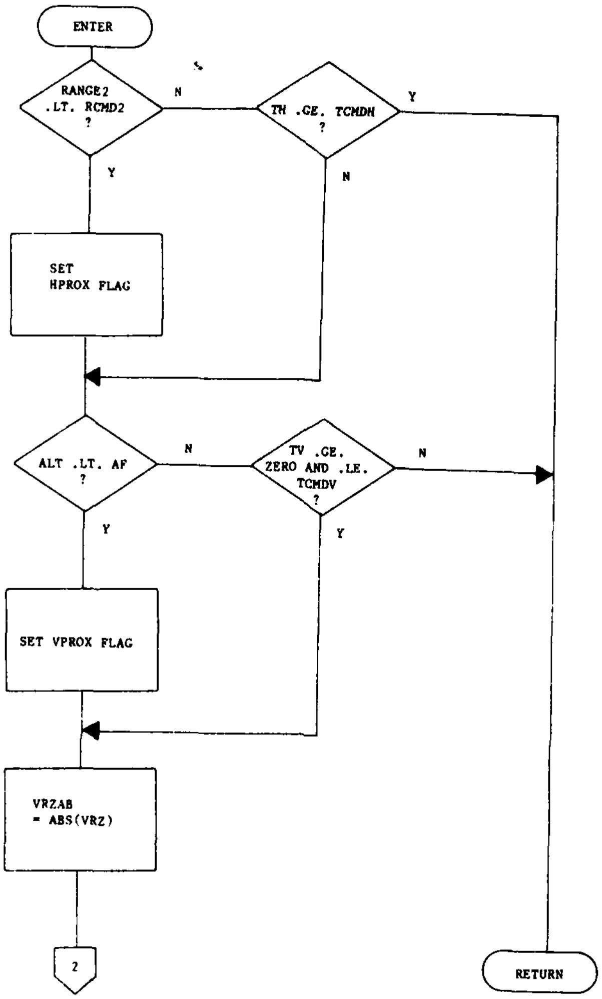


FIGURE 7-5
SCMDF ROUTINE (Page 1 of 3)

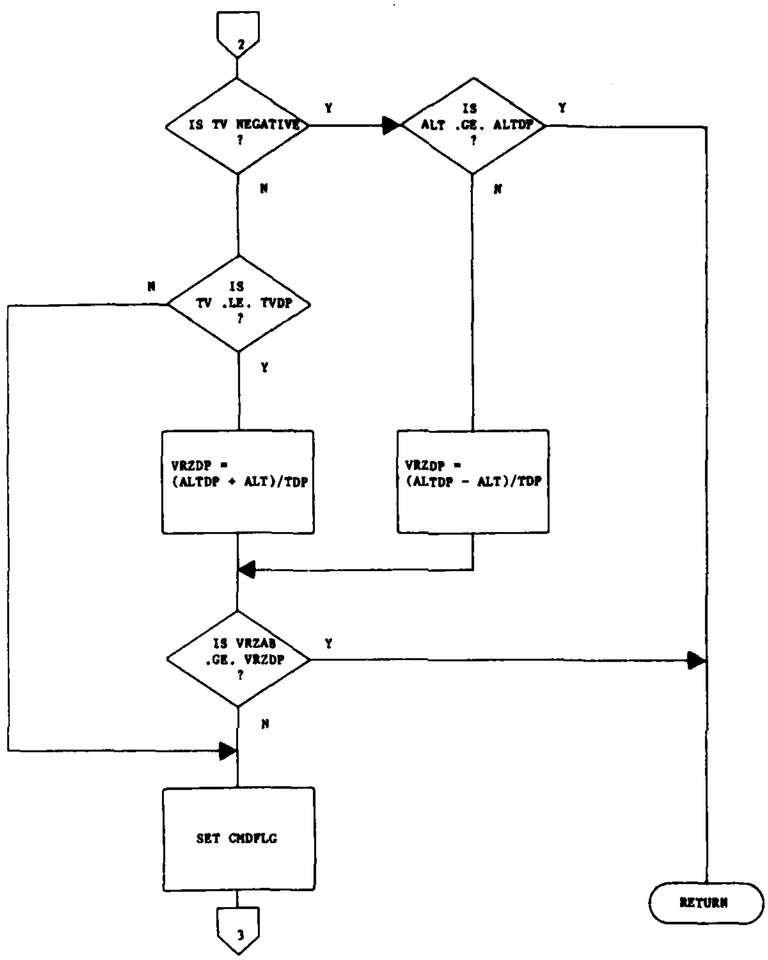


FIGURE 7-6
SCMDF ROUTINE (Page 2 of 3)

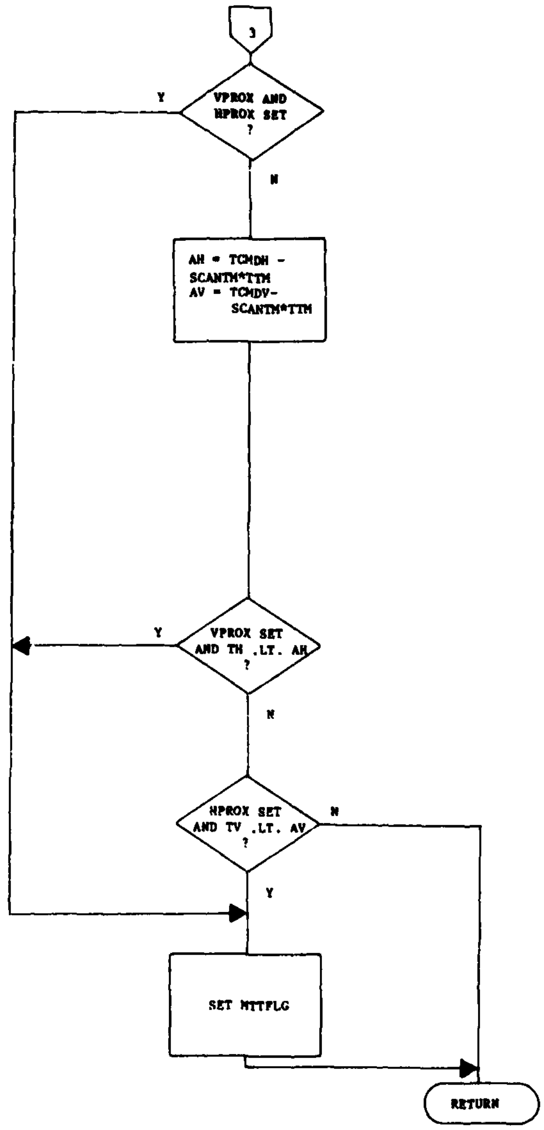


FIGURE 7-6
SCMDF ROUTINE (Page 3 of 3)

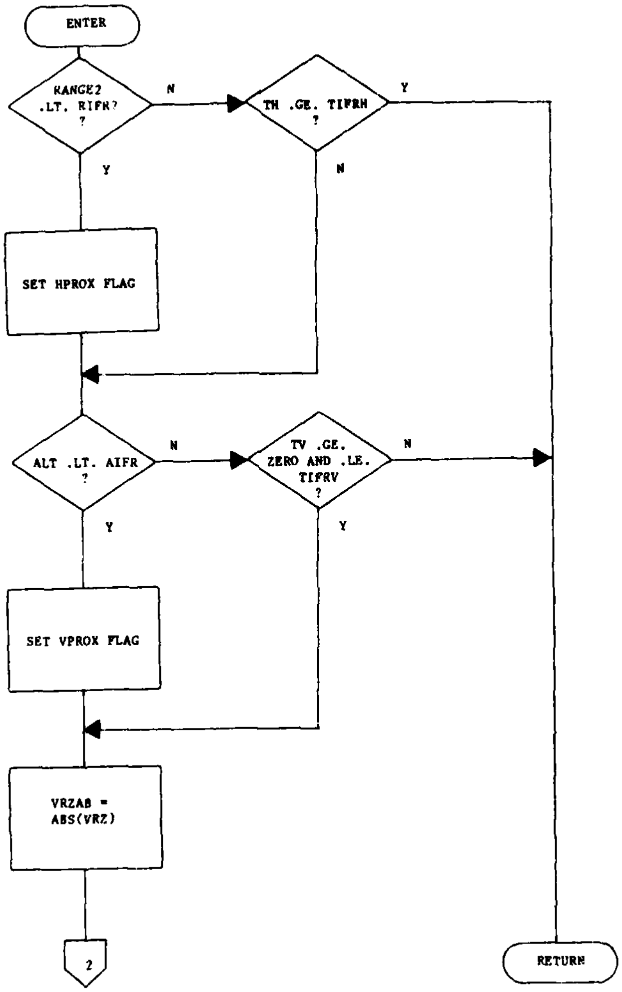


FIGURE 7-6
SIFRF ROUTINE (PAGE 1 OF 3)

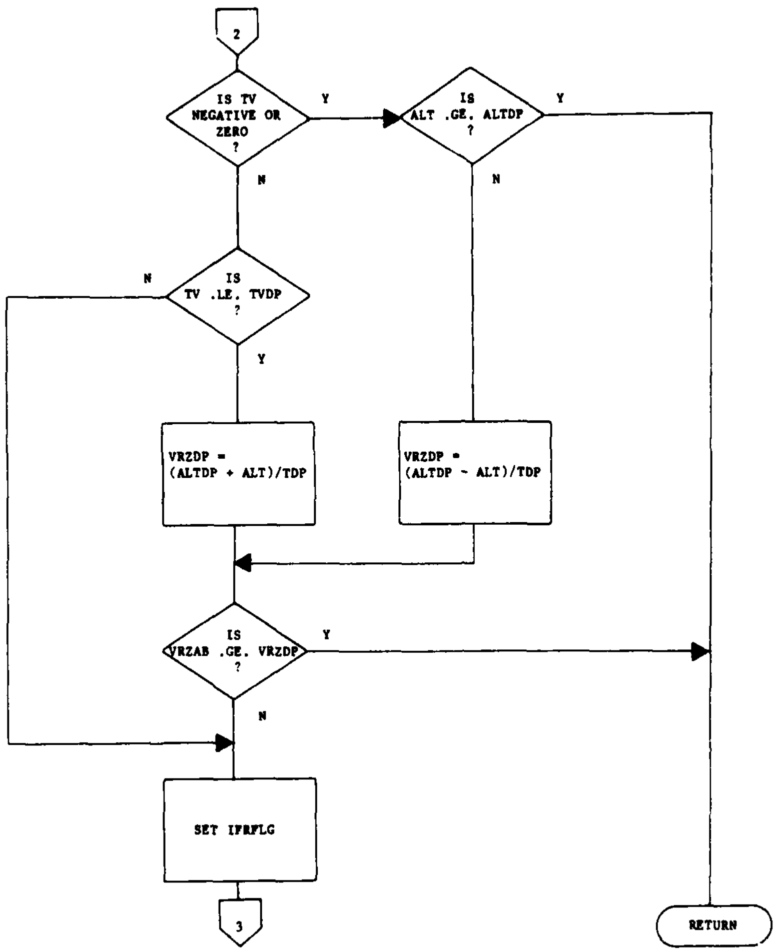


FIGURE 7-6
SIFRF ROUTINE (PAGE 2 OF 3)

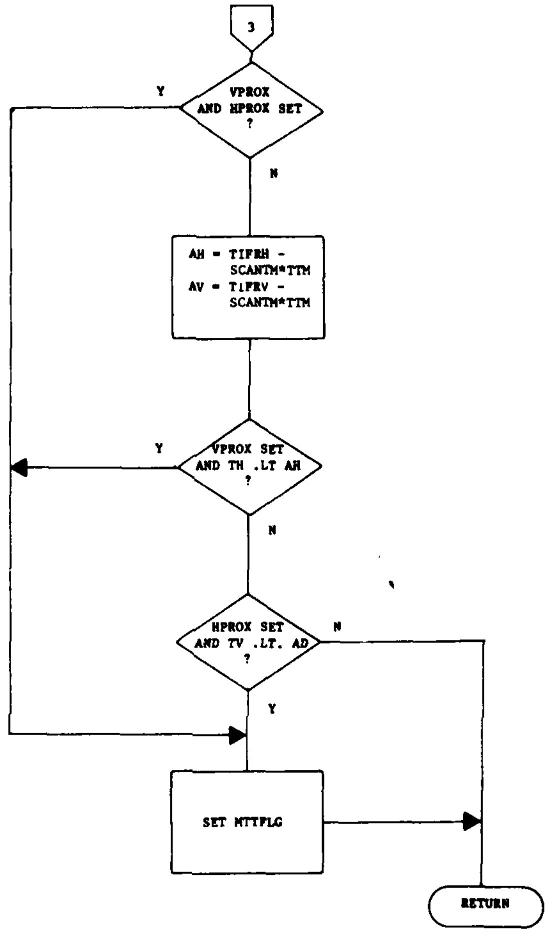


FIGURE 7-6
SIFRF ROUTINE (PAGE 3 OF 3)

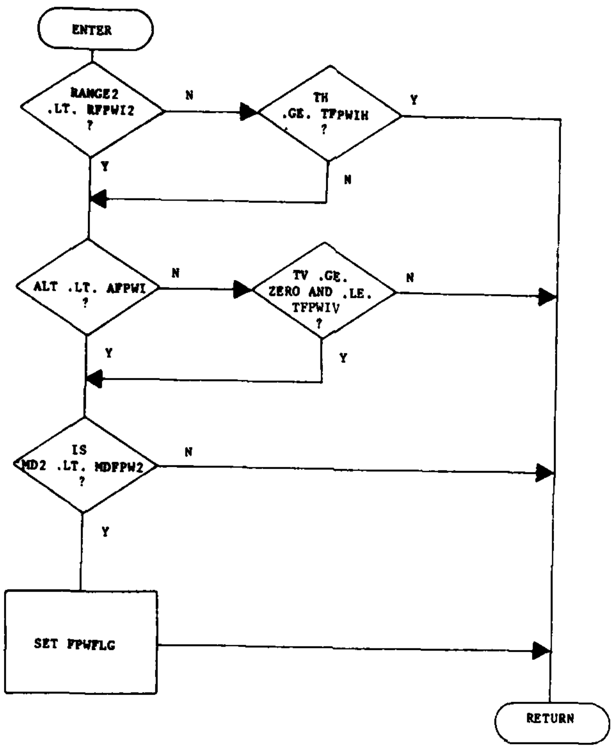


FIGURE 7-7
SFPWF ROUTINE

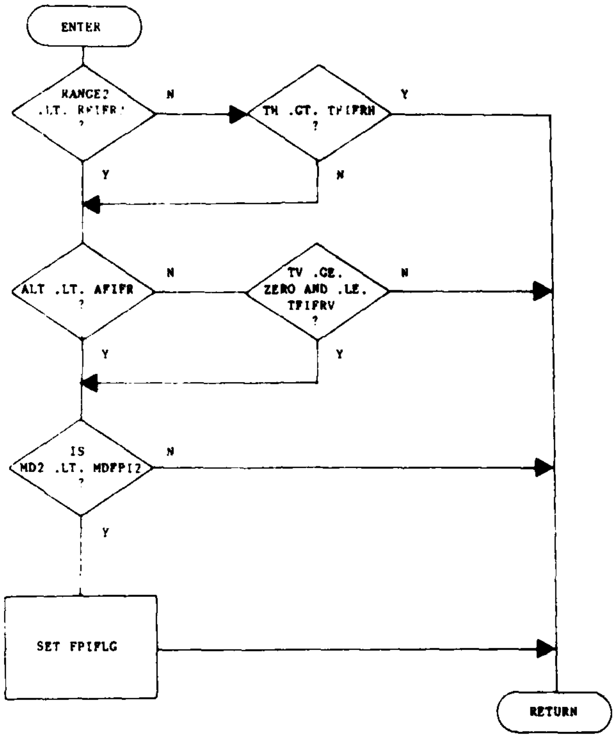


FIGURE 7-8
SFPIF ROUTINE

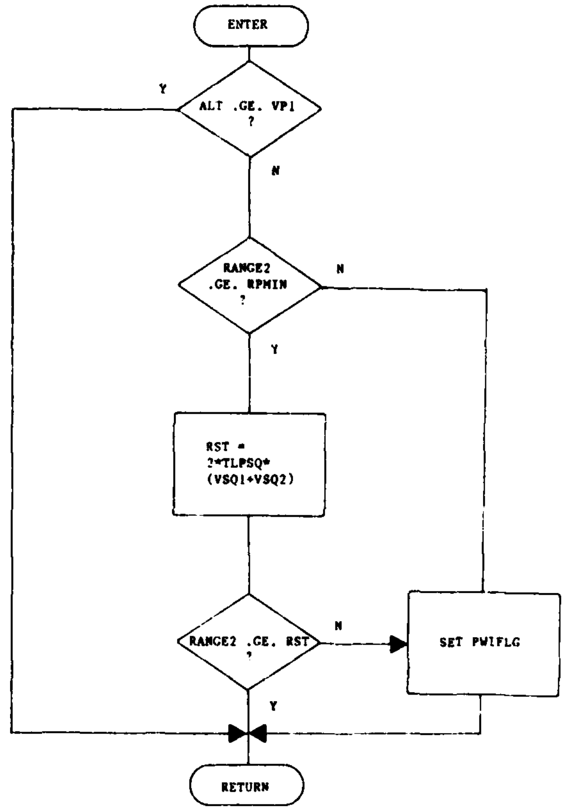


FIGURE 7-8
SPWIF ROUTINE

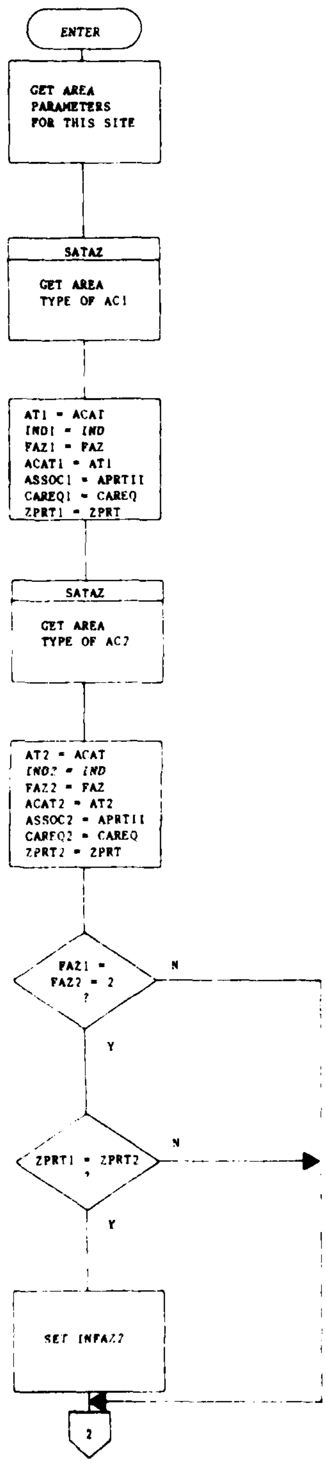


FIGURE 7-10
SENAT ROUTINE (Page 1 of 2)

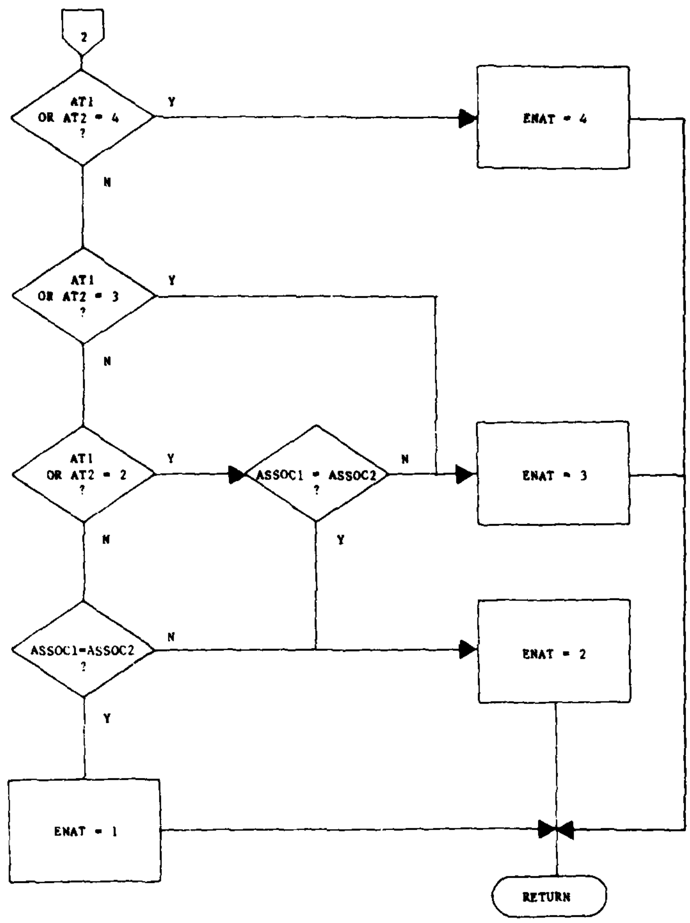


FIGURE 7-10
SENAT ROUTINE (Page 2 of 2)

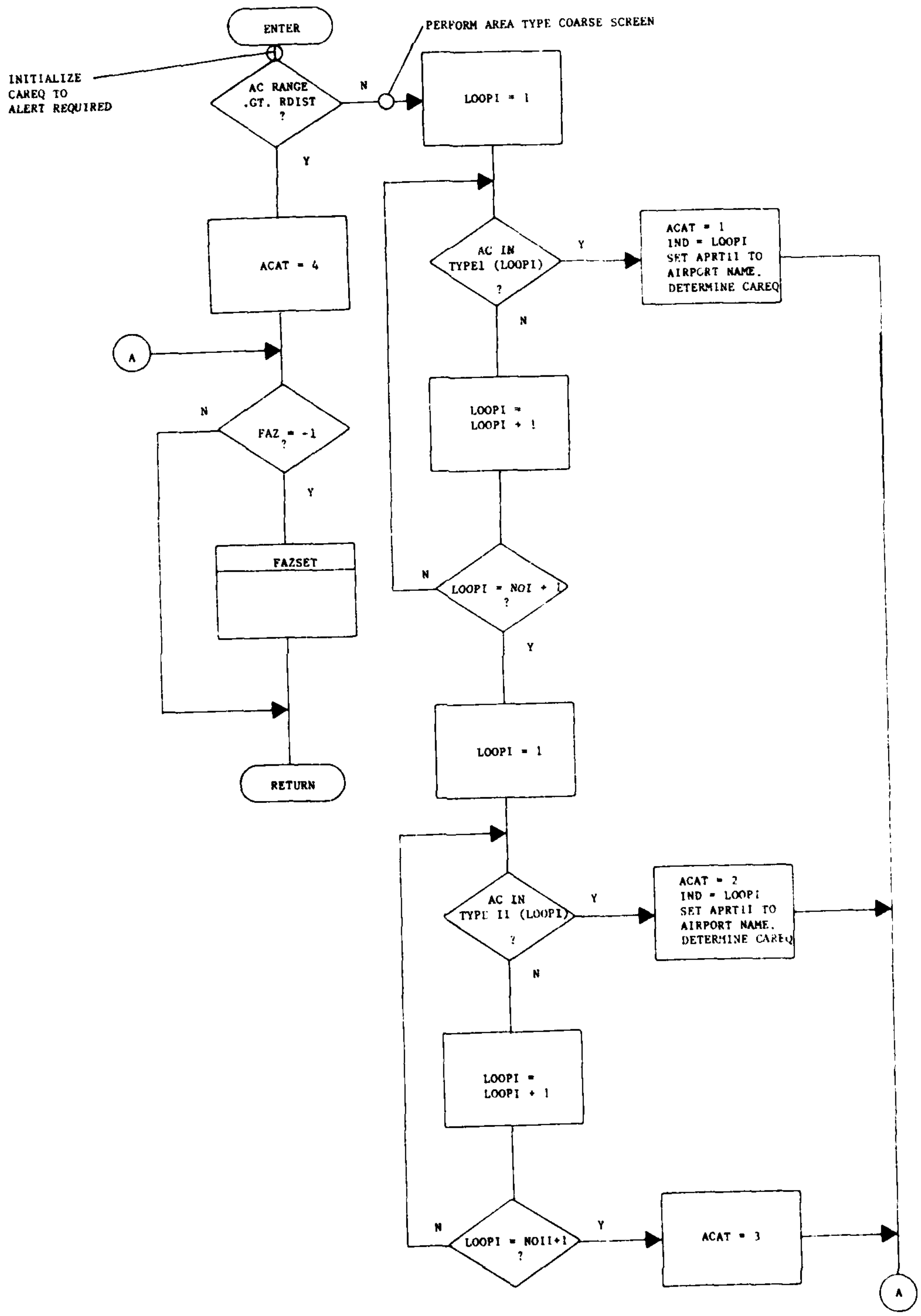


FIGURE 7-11
SATAZ ROUTINE

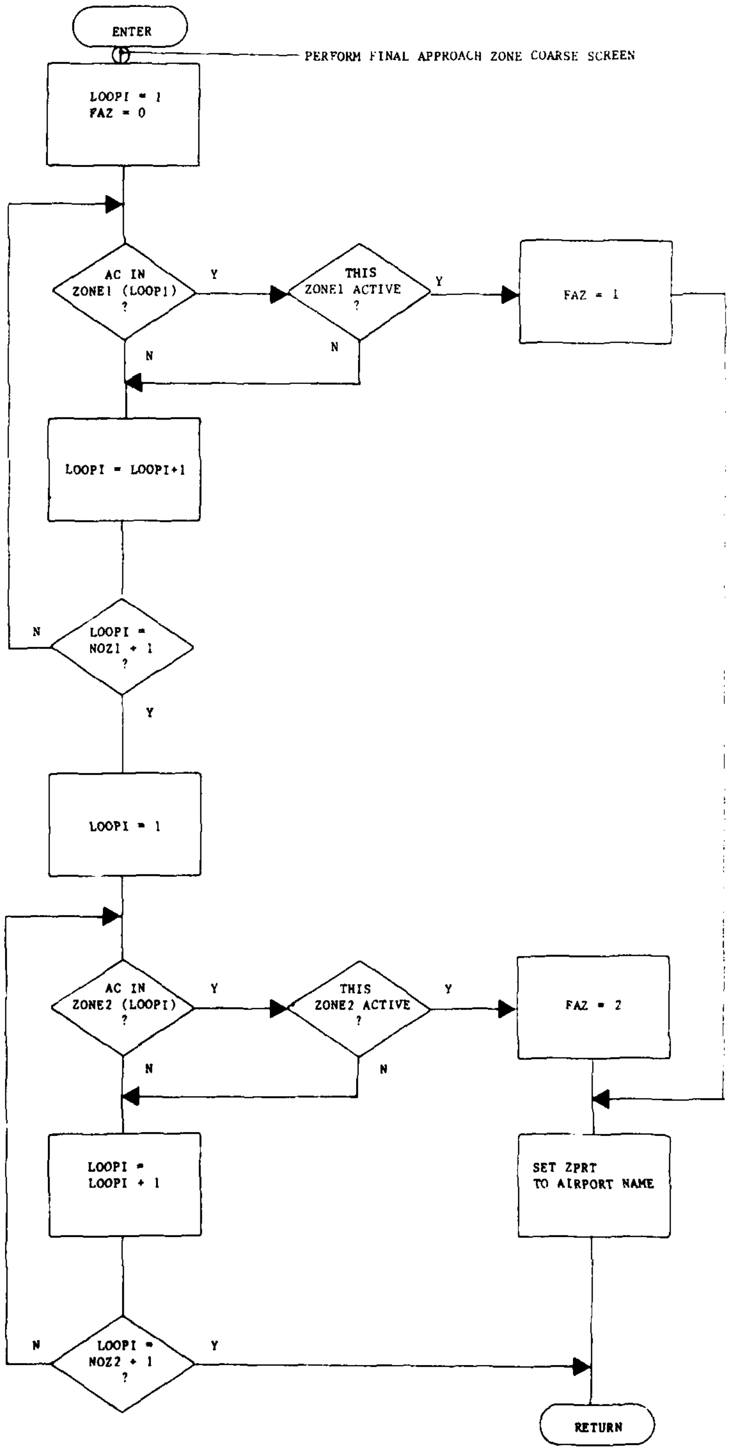


FIGURE 7-12
FAZSET ROUTINE

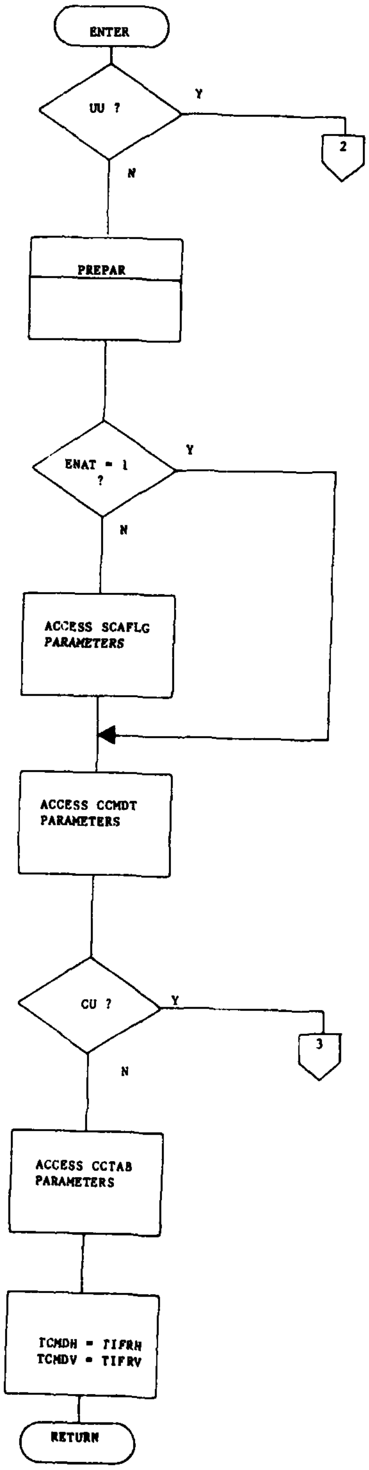


FIGURE 7-13
SETPAR ROUTINE (Page 1 of 3)

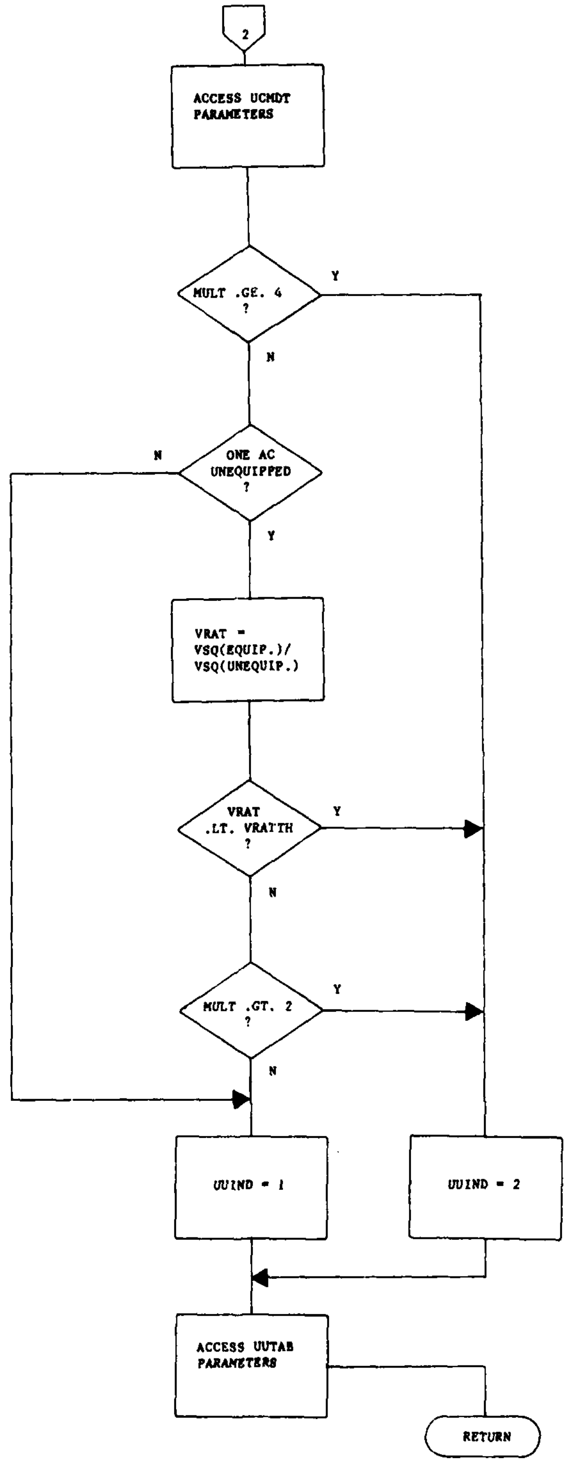


FIGURE 7-13
SETPAR ROUTINE (Page 2 of 3)

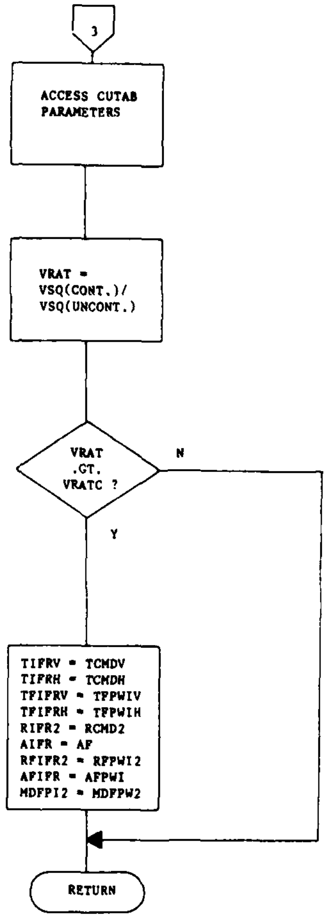


FIGURE 7-13
SETPAR ROUTINE (Page 3 of 3)

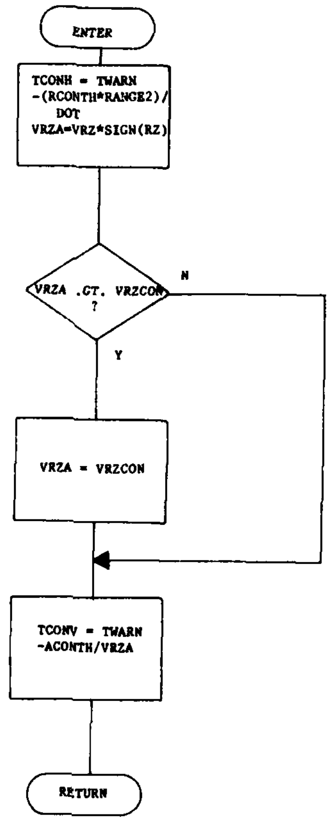


FIGURE 7-14
PREPAR ROUTINE

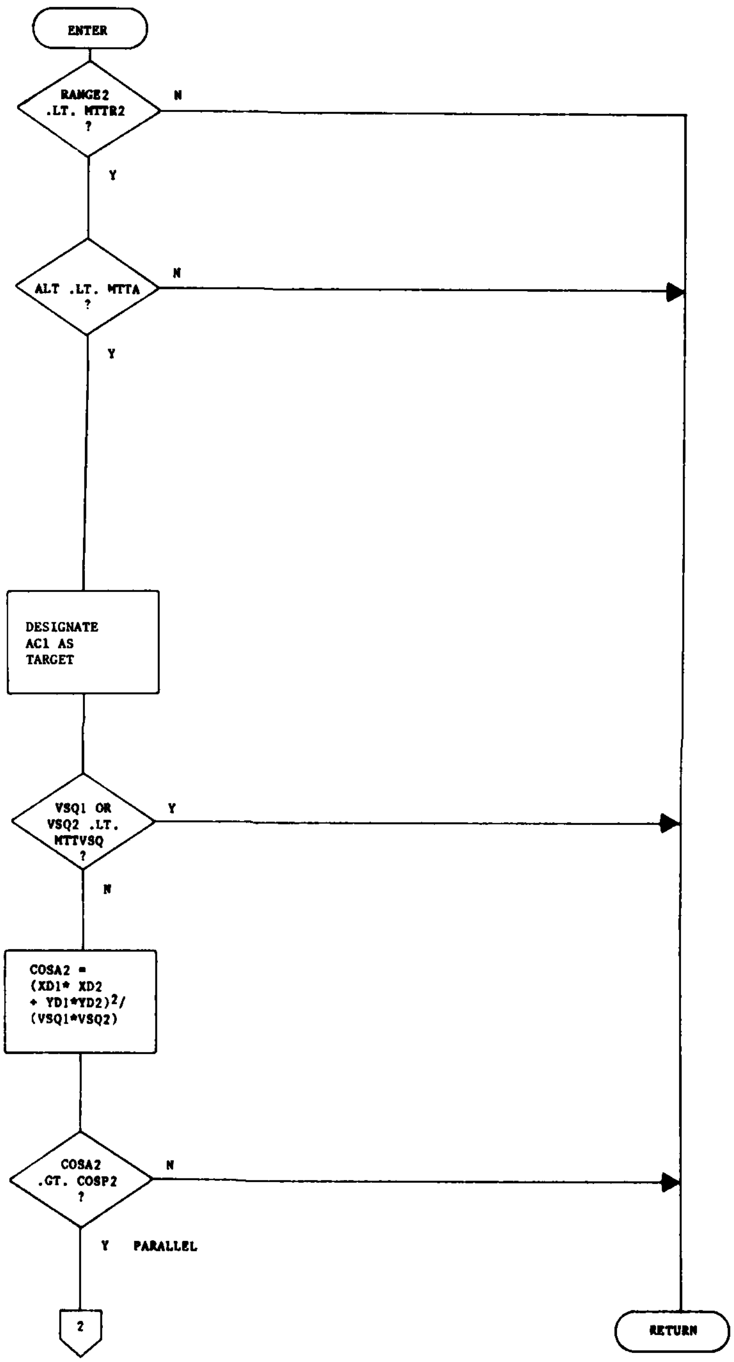


FIGURE 7-15
SMTTF ROUTINE (Page 1 of 2)

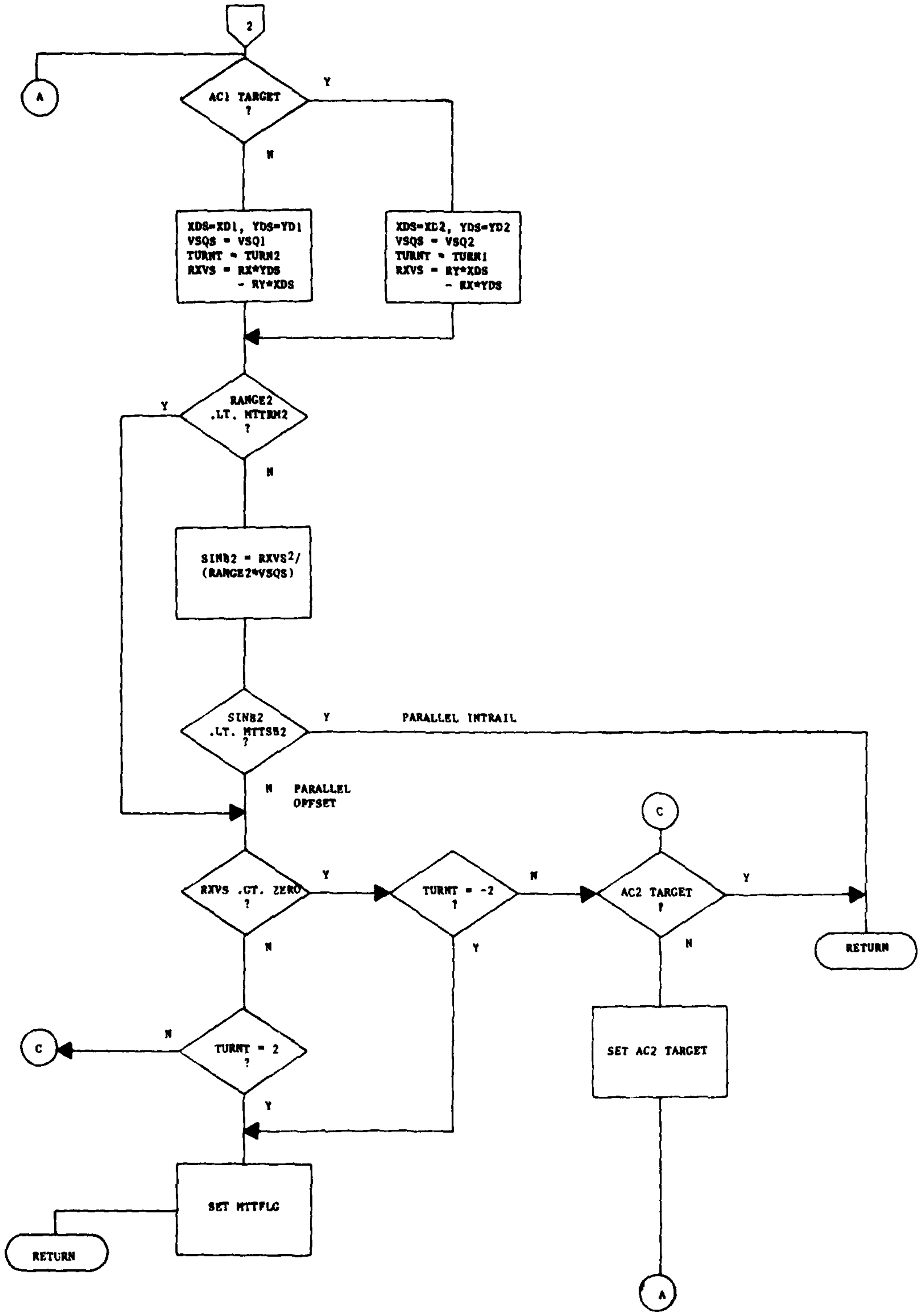


FIGURE 7-15
SMTTF ROUTINE (Page 2 of 2)

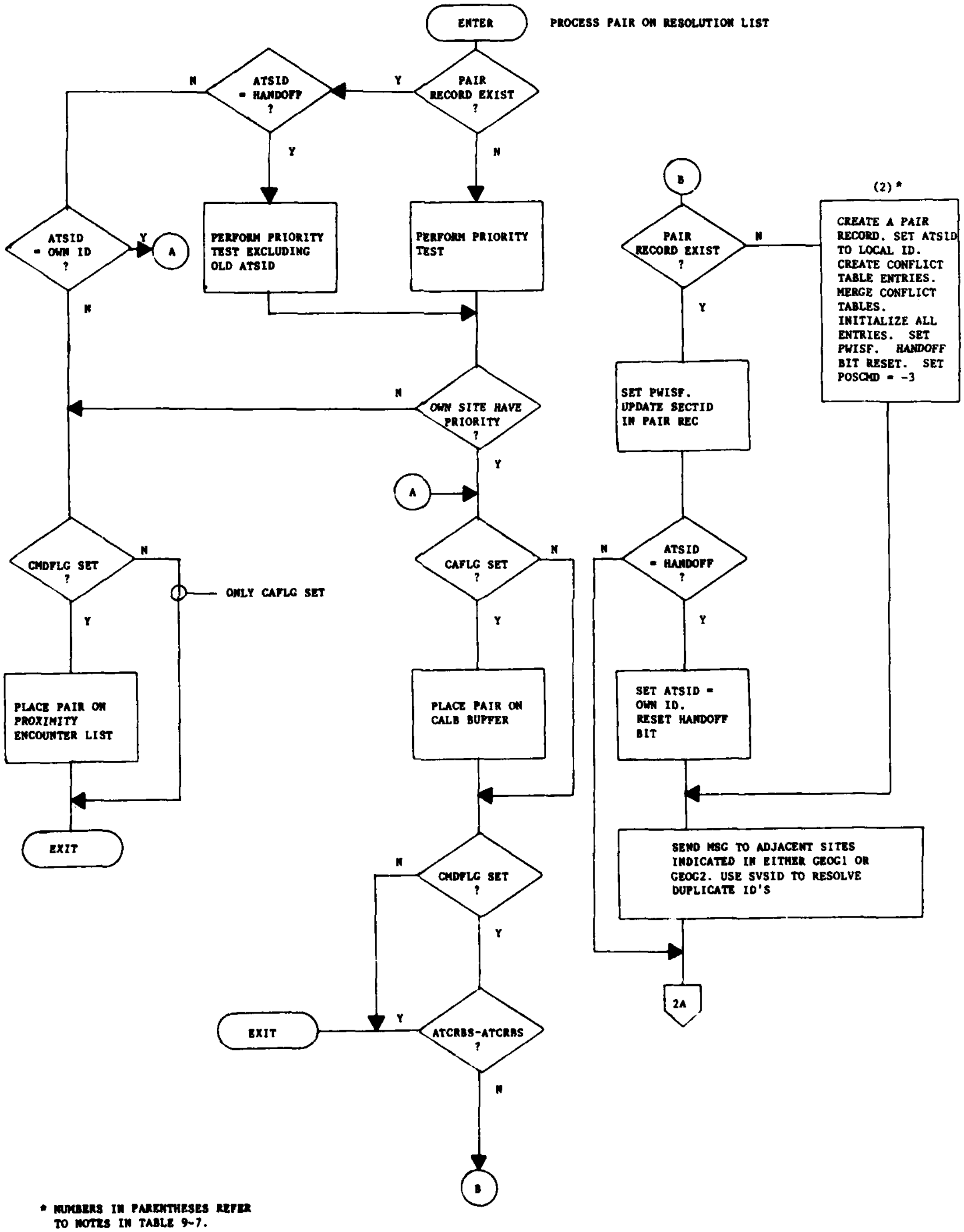


FIGURE 7-16
SEAM PAIR TASK (Page 1 of 2)

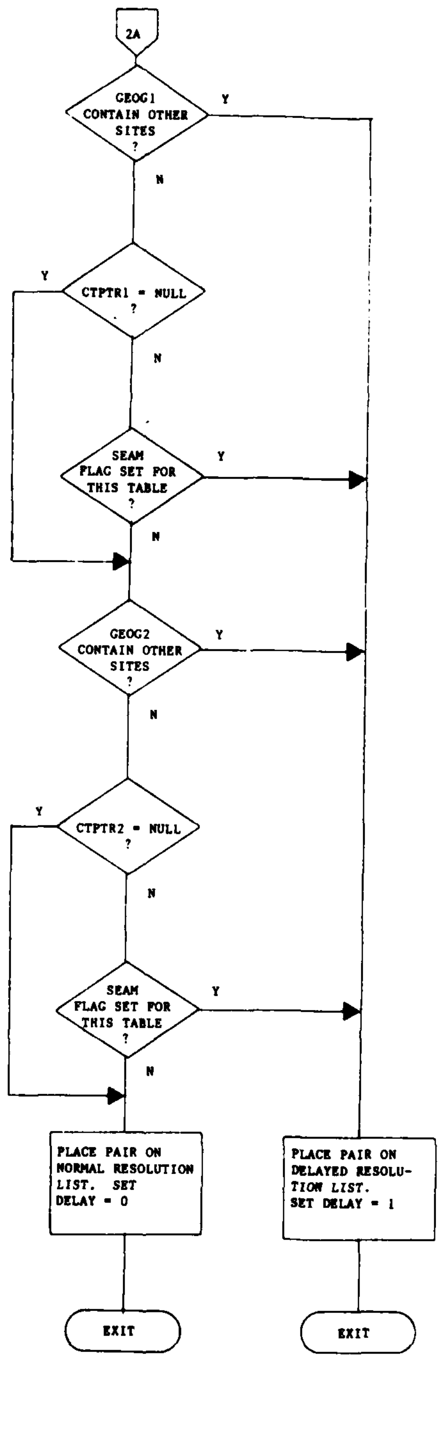


FIGURE 7-16
SEAM PAIR TASK (Page 2 of 2)

TABLE 7-1

FLAGS APPROPRIATE FOR A PARTICULAR AIRCRAFT STATE

UNEQUIPPED/UNCONTROLLED	-	none
UNEQUIPPED/CONTROLLED	-	CAFLG, ICAFLG
EQUIPPED/UNCONTROLLED	-	CMDFLG, FPWFLG, PWIFLG
EQUIPPED/CONTROLLED	-	IFRFLG, FPIFLG, CMDFLG, PWIFLG, CAFLG, ICAFLG

TABLE 7-2

ROUTINE AND DETECT FLAG CROSS-REFERENCE TABLE

FLAG	ROUTINE MODULE WHICH MAY SET FLAG
MTTFLG	SMTTF, SCMDF, SIFRF
PWIFLG	SPWIF
FPWFLG	MTT*, SFPWF
FPIFLG	MTT*, SFPIF
CMDFLG	MTT*, SCMDF
IFRFLG	MTT*, SIFRF
CAFLG	SCAFLG
ICAFLG	SCAFLG

* See text for explanation

TABLE 7-3

AIRCRAFT PAIR STATE AND ROUTINE CROSS-REFERENCE TABLE

	EQ/EQ	UNEQ/UNEQ	UNEQ/EQ
UNC/UNC	SENAT, SETPAR SFPWF, SCMDF SPWIF	None	SENAT, SETPAR SFPWF, SCMDF SPWIF, SMTTF
CONT/CONT	SENAT, SETPAR SCAFLG, SFPIF SIFRF, SPWIF	SENAT, SETPAR SCAFLG	SENAT, SETPAR SCAFLG, SFPIF SIFRF, SPWIF SMTTF
UNC/CONT	SENAT, SETPAR SCAFLG, SFPWF SCMDF, SFPIF SIFRF, SPWIF	SENAT, SETPAR SCAFLG	SENAT, SETPAR SCAFLG, SFPIF SIFRF, SPWIF SMTTF
CONT/UNC	SENAT, SETPAR SCAFLG, SFPWF SCMDF, SFPIF SIFRF, SPWIF	SENAT, SETPAR SCAFLG	SENAT, SETPAR SCAFLG, SFPWF SCMDF, SPWIF SMTTF

UNC - UNCONTROLLED   EQ - EQUIPPED
CONT - CONTROLLED   UNEQ - UNEQUIPPED

TABLE 7-4

PREPAR PARAMETERS

AREA TYPE	TWARN
4	44.8 sec
3	36.8 sec
2	36.8 sec
1	36.8 sec

AREA TYPE	RCONTH	ACONTH
3 or 4	1.2 nmi	375 ft
2	.75 nmi	275 ft
1	.75 nmi	275 ft

VRZCON = -300 FPM

TABLE 7-5

SCAFLG PARAMETERS

AREA TYPE	RCON2	AFCON	MDCON2
3 or 4	1.44 nmi^2	375 ft	1.44 nmi^2
2	.5625 nmi^2	275 ft	.5625 nmi^2

ZONE TYPE	ZRCON2	ZAFCON
2	.25 nmi^2	275 ft

TABLE 7-6

CONTROLLED/UNCONTROLLED TABLE (CUTAB)

MULT	AREA TYPE	EQUIP	TFPWIV TFPWIH			TCMDV TCMDH		
			S	L (sec)	U	S	L (sec)	U
LE3	4	BU	0	38	68	15	38	53
LE3	3	BU	0	30	60	15	30	45
LE3	2	BU	0	30	60	15	30	45
LE3	1	BU	0	30	60	15	30	45
LE3	4	CN	0	38	68	15	38	53
LE3	3	CN	0	30	60	15	30	45
LE3	2	CN	0	30	60	15	30	45
LE3	1	CN	0	30	60	15	30	45
GT3	4	BU	0	60	68	15	60	60
GT3	3	BU	0	60	68	15	60	60
GT3	2	BU	0	60	68	15	60	60
GT3	1	BU	0	60	68	15	60	60
GT3	4	CN	0	60	68	15	60	60
GT3	3	CN	0	60	68	15	60	60
GT3	2	CN	0	60	68	15	60	60
GT3	1	CN	0	60	68	15	60	60

MULT	AREA TYPE	EQUIP	TFIFRV TFIFRH			TIFRV TIFRH		
			S	L	U	S	L	U
LE3	4	BU	0	38	68	35	38	38
LE3	3	BU	0	30	60	35	30	30
LE3	2	BU	0	30	60	35	30	30
LE3	1	BU	0	30	60	35	30	30
LE3	4	CN	0	38	68	35	38	38
LE3	3	CN	0	30	60	35	30	30
LE3	2	CN	0	30	60	35	30	30
LE3	1	CN	0	30	60	35	30	30
GT3	4	BU	0	60	68	35	60	60
GT3	3	BU	0	60	68	35	60	60
GT3	2	BU	0	60	68	35	60	60
GT3	1	BU	0	60	68	35	60	60
GT3	4	CN	0	60	68	35	60	60
GT3	3	CN	0	60	68	35	60	60
GT3	2	CN	0	60	68	35	60	60
GT3	1	CN	0	60	68	35	60	60

TABLE 7-6

CONTROLLED/UNCONTROLLED TABLE (CUTAB)
(Concluded)

PARAMETER	MODULE	AREA TYPE		
		3 or 4	2	1
RCMD2	SCMDF	1.0 nmi^2	.5625 nmi^2	.5625 nmi^2
AF	SCMDF	750 ft	750 ft	750 ft
RIFR2	SIFRF	.5625nmi^2	.5625 nmi^2	.5625 nmi^2
AIFR	SIFRF	750 ft	750 ft	750 ft
RFPWI2	SFPWF	1.44 nmi^2	.5625 nmi^2	.5625 nmi^2
AFPWI	SFPWF	1000 ft	1000 ft	1000 ft
MDFPW2	SFPWF	1.44 nmi^2	.5625 nmi^2	.5625 nmi^2
RFIFR2	SFPIF	1.44 nmi^2	.5625 nmi^2	.5625 nmi^2
AFIFR	SFPIF	1000 ft	1000 ft	1000 ft
MDFPI2	SFPIF	1.44 nmi^2	.5625 nmi^2	.5625 nmi^2

NOTE: Equipage is keyed as follows:

BU - Either both AC equipped or else only uncontrolled AC equipped.

CN - Either controlled AC only is equipped or else neither AC is equipped.

Multiplicity (MULT) is keyed as follows:

LE - Less than or equal to

GT - Greater than

TABLE 7-7

CONTROLLED/CONTROLLED TABLE (CCTAB)

MULT	AREA TYPE	TFIFRV TFIFRH S	TFIFRV TFIFRH L (sec)	TFIFRV TFIFRH U	TIFRV TIFRH S	TIFRV TIFRH L (sec)	TIFRV TIFRH U
LE3	4	0	38	38	35	38	38
LE3	3	0	30	60	35	30	30
LE3	2	0	30	60	35	30	30
LE3	1	0	30	60	35	38	38
GT3	4	0	60	68	35	60	60
GT3	3	0	60	60	35	60	60
GT3	2	0	60	60	35	60	60
GT3	1	0	60	60	35	60	60

PARAMETER	MODULE	AREA TYPE 3 or 4	AREA TYPE 2	AREA TYPE 1
RIFR2	SIFRF	.5625 nmi^2	.5625 nmi^2	.5625 nmi^2
AIFR	SIFRF	750 ft	750 ft	750 ft
RFIFR2	SFPIF	.5625 nmi^2	.5625 nmi^2	.5625 nmi^2
AFIFR	SFPIF	1000 ft	1000 ft	1000 ft
MDFPI2	SFPIF	.5625 nmi^2	.5625 nmi^2	.5625 nmi^2

NOTE: Parameters with (S, L, U) designations are to be computed as follows:

$$\text{Parameter V} = (\text{TCONV} - \text{S})\Big|_{\underline{L}}^{\underline{U}}$$

$$\text{Parameter H} = (\text{TCONH} - \text{S})\Big|_{\underline{L}}^{\underline{U}}, \text{ where}$$

TCONV, TCONH are computed in PREPAR, and $(\quad)\Big|_{\underline{L}}^{\underline{U}}$ designates limit of ( ) to U above, L below.

TABLE 7-8

UNCONTROLLED/UNCONTROLLED TABLE (UUTAB)

UUIND	AREA TYPE	TFPWIH TFPWIV	TCMDH	TCMDV
1	4	53 sec	38 sec	38 sec
1	3	45 sec	30 sec	30 sec
1	2	45 sec	30 sec	30 sec
1	1	45 sec	30 sec	30 sec
2	4	53 sec	38 sec	38 sec
2	3	53 sec	38 sec	38 sec
2	2	53 sec	38 sec	38 sec
2	1	53 sec	38 sec	38 sec

PARAMETER	MODULE	AREA TYPE		
		3 or 4	2	1
RCMD2	SCMDF	1.0 nmi^2	1.0 nmi^2	1.0 nmi^2
AF	SCMDF	750 ft	750 ft	750 ft
RFPWI2	SFPWF	1.0 nmi^2	1.0 nmi^2	1.0 nmi^2
AFPWI	SFPWF	1000 ft	1000 ft	1000 ft
MDFPW2	SFPWF	1.2 nmi^2	1.2 nmi^2	1.2 nmi^2

TABLE 7-9

UCMDT/CCMDT PARAMETERS

ALTDP = 650 ft		
TVDP = 8.0 sec		UCMDT Assignments
TDP = 23.0 sec		
ALTDP = 650 ft		
TVDP = 8.0 sec		CCMDT Assignments
TDP = 23.0 sec		

TABLE 7-10

SATAZ and FAZSET PARAMETERS

Airport Area Table

NOI - Number of type 1 areas (site specific)
NOII - Number of type 2 areas (site specific)

RDIST = 83.3 nmi (for sensor azimuth jitter of .06°)
ZHMNX, ZHMXX, ZHMNY, ZHMXY - COARSE SCREEN PARAMETERS

A1, B1, C1 A2, B2, C2 C3, C4 ZMIN, ZMAX	One set for each type 1 and type 2 area. Allow for 25 sets.
D1, E1, F1	Allow up to five sets for each type 1 area.

An aircraft is in a given area type 1 or 2 if and only if its position (X, Y, Z) satisfies:

(1) C1 .LE. (A1 * X + B1 * Y) .LE. C2

(2) C3 .LE. (A2 * X + B2 * Y) .LE. C4

(3) ZMIN .LE. Z .LE. ZMAX

(4) (D1 * X + E1 * Y) .LE. F1 (for area type 1 only)

Equation (4) is a generic equation to be satisfied for each set D1, E1, F associated with a given area 1. In addition, each area type 1 and 2 will have a flag (CAREQ) indicating whether controller alert processing is appropriate for that particular area or not.

Each group of defining parameters for an airport type 1 or 2 will have an airport name associated with it. This name allows areas from different airports to be differentiated in spatial dependent logic in the Detect Task.

Airport Zone Table

NOZ1 - Number of zone 1 areas (site specific)
NOZ2 - Number of zone 2 areas (site specific)
ZJMNX, ZJMXX, ZJMNY, ZJMXY - COARSE SCREEN PARAMETERS

AZONL1, AZONW1 BZONL1, BZONW1 CZONL1, CZONW1 LZON1, WZON1, ZZON1	One set for each zone 1. Allow for 10 sets.

TABLE 7-10

SATAZ and FAZSET PARAMETERS
(Concluded)

Airport Area Table

AZONL2, AZONW2 BZONL2, BZONW2 CZONL2, CZONW2 LZON2, WZON2 AZONZ2, BZONZ2 CZONZ2, DZONZ2	One set for each zone 2. Allow for 20 sets.

ZZON2 = 200 ft
COAA2 = .9698

An aircraft is in a given zone 1 if its position (X, Y, Z) satisfies:

(1) -WZON1 .LE.(AZONW1 * X + BZONW1 * Y + CZONW1) .LE. WZON1

(2) -LZON1 .LE.(AZONL1 * X + BZONL1 * Y + CZONL1) .LE. LZON1

(3) Z .LE. ZZON1

An aircraft is in a given zone 2 if its position (X, Y, Z) and horizontal velocity (XD, YD) satisfy:

(4) -WZON2 .LE. (AZONW2 * X + BZONW2 * Y + CZONW2) .LE. WZON2

(5) -LZON2 .LE. (AZONL2 * X + BZONL2 * Y + CZONL2) .LE. LZON2

(6) -ZZON2 .LE. (AZONZ2 * X + BZONZ2 * Y + CZONZ2 * Z + DZONZ2).LE. ZZON2

(7) (XD * AZONL2 + YD * BZONL2) .LT. 0

(8) $(XD * AZONL2 + YD * BZONL2)^2$.GE. (XD^2+YD^2) * COAA2

NOTE: AZONL2 and BZONL2 are the east and north components of a normal horizontal vector parallel to the main axis of the given zone 2 and pointing away from the air field.

Each type 2 final approach zone will have an externally enterable flag indicating whether the given type 2 zone is currently active or not.

Each group of defining parameters for a zone 1 or 2 will have an airport name associated with it. This name allows zones from different airports to be differentiated in spatial dependent detection logic.

TABLE 7-11

SYNOPSIS OF DETECT PARAMETERS
(Grouped by Invoking Routine)

	<u>DETECT</u>
ADET	92.5 sec^2
AFDET	Maximum (ZAFCON, AFCON, AF AIFR, AFPWI, AFIFR)
BDET	.107 nmi^2
DOTTH	10 nmi * knt
TLA	Set by coarse screen
VMDTH	100 knt^2
VRZTH	15 ft/min
RDET	Maximum (ZRCON2, RCON2, RCMD2, RIFR2, RFPWI2, RFIFR2)
	<u>SCAFLG</u>
AFCON	
MDCON2	Table look-up.
RCON2	
TCONH	Computed from table look-up (in PREPAR).
TCONV	
ZAFCON	275 ft
ZRCON	.25 nmi^2
	<u>SCMDF</u>
AF	Table look-up.
RCMD2	
TCMDH	Table look-up or computed from
TCMDV	table look-up.
ALTDP	
TDP	Vertical divergence parameters,
TVDP	from CCMDT or CUMDT.
TTM	2' SCANS
	<u>SIFRF</u>
AIFR	Table look-up.
RIFR2	
TIFRH	Computed from table look-up.
TIFRV	
ALTDP	
TDP	See SCMDF.
TVDP	
TTM	2 scans

TABLE 7-11

SYNOPSIS OF DETECT PARAMETERS
(Continued)

SFPWF

AFPWI MDFPW2 RFPWI2	Table look-up.
TFPWIH TFPWIV	Table look-up or computed from table look-up.

SFPIF

AFIFR MDFPI2 RFIFR2	Table look-up.
TFIFRH TFIFRV	Computed from table look-up.

SPWIF

RPMIN	4.0 nmi^2
TLPSQ	900 sec^2
VP1	2000 ft

SATAZ/FAZSET

A1 B1 C1 A2 B2 C2 C3 C4 ZMIN ZMAX	One set for each type I and type II area. Site specific.
D1 E1 F1	Allow up to 5 sets for each area type I. Site specific.
NOI NOII	Site specific.

TABLE 7-11

SYNOPSIS OF DETECT PARAMETERS
(Continued)

SATAZ/FAZSET (Continued)

RDIST	83.3 nmi
NOZ1 NOZ2	Site Specific
AZONL1 AZONW1 BZONL1 BZONW1 CZONL1 CZONW1 LZON1 WZON1 ZZON1	Constants, used in final approach zone (FAZ) logic. One set for each type 1 final approach zone. Site specific.
AZONL2 AZONW2 AZONZ2 BZONL2 BZONW2 BZONZ2 CZONL2 CZONW2 CZONZ2 DZONZ2 LZONE2 WZONE2	One set for each type 2 final approach zone. Allow for 20 sets. Site specific.

ZZON2 = 200 ft
COAA2 = .9698

SETPAR

VRATTH	2.25
VRATC	2.25

TABLE 7-11

SYNOPSIS OF DETECT PARAMETERS
(Concluded)

PREPAR

ACONTH RCONTH TWARN	Table look-up.
VRZCON	-300 fpm

SMTTF

MTTR2	3.25 nmi^2
MTTA	1000 ft
MTTVSQ	325 knt^2
COSP2	.981
MTTSB2	.117
MTTRM2	.00244 nmi^2

CAMAN

CAMR2	3.25 nmi^2
CAMA	1000 ft
CAMVSQ	325 knt^2
CAMCP2	.981
MTTRM2	.00244 nmi^2
CAMSB2	.117

TABLE 7-12

LOGICAL CONTENT OF AN ENTRY ON AN ENCOUNTER LIST

ACID1	-	Identification of first aircraft in pair.
ACID2	-	Identification of second aircraft in pair.
ALT	-	Absolute value of current altitude separation.
CAFLG	-	Controller alert for aircraft pair flag.
CMDFLG	-	Resolution advisory for aircraft pair flag.
CPSID	-	Identity of the sector with which this encounter is associated and processed
DOT	-	Dot product of relative separation and relative velocity vectors.
ENAT	-	Encounter area type.
FPIFLG	-	Threat advisory to controlled aircraft flag.
FPWFLG	-	Threat advisory to uncontrolled aircraft flag.
ICAFLG	-	Bypass the 3-out-of-5 logic for controller alert flag.
IFRFLG	-	Resolution advisory to controlled aircraft flag.
LETID	-	List encounter type identification, indicating the 5 possible encounter lists to which the entry belongs.
MD2	-	Miss distance squared.
MTTFLG	-	Bypass 2-out-of-3 rule for resolution advisory flag.
PWIFLG	-	Proximity advisory for aircraft pair flag.
RANGE2	-	Range squared.
TH	-	Time until a horizontal separation threshold (DSQ) is violated.
TV	-	Time to coincidence in the vertical direction.

1. If a potentially hazardous situation exists, i.e., should a Proximity or Threat Advisory Message be sent to the aircraft.

2. If the controller should know about the potential conflict situation.

3. If an aircraft should get a Resolution Advisory Message and when (it does not determine the type of resolution).

The Detect Task utilizes the state vectors of the aircraft pair from the Coarse Screen Processing Task to determine if the ATARS system must take action on this pair. Action will be taken if an estimate of the time to a separation violation is below a threshold or the present separation between aircraft is less than a required minimum. Specifically the primary outputs of the task are the eight flags:

1. PWIFLG - set if a proximity advisory is required for the pair.

2. FPWFLG - set if a threat advisory is required for uncontrolled aircraft in the pair.

3. FPIFLG - set if a threat advisory is required for controlled aircraft in the pair.

4. CMDFLG - set if, based on this cycle, an ATARS Resolution Advisory Message is requested for the pair. This flag is in no way dependent on controlled or uncontrolled status of the aircraft. It must be set if there is a resolution advisory.

5. IFRFLG - set if a controlled aircraft is to receive a resolution advisory. This flag forces the setting of CMDFLG.
CMDFLG can be set without IFRFLG being set, however.

6. CAFLG - set if a controller alert is required for this pair.

7. ICAFLG - set if the three out of five sliding window logic is to be bypassed for controller alerts.

8. MTTFLG - set if the two out of three sliding window logic will be bypassed in the resolution section. Setting the MTTFLG implies that the appropriate resolution flag has been set.

These flags are used during the resolution phase and when the ATARS messages are built for output to the data link. A review of Sections 2.2.1 through 2.2.3 will be helpful in understanding the use of these flags and in understanding the Detect Task, itself. Table 7-1 details which flags can be set for any combination of equipment and controlled status for a single aircraft. The flags set for an aircraft pair, the output of detection, would simply be the combination of two such conditions. Table 7-2 lists routines of the Detect Task and which flags each routine can set. The designation MTT refers to the post-processing section of the SMTTF module (Figure 7-2, Page 8 of 9). This section sets the appropriate flags if a maneuvering target threat has been indicated by SMTTF. Table 7-3 shows which routines are called for the particular equipage and control state of the aircraft pair. By combining with Table 7-2 one can determine the possible flag settings for an aircraft pair state.

The Detect Task bases the decision on when to set flags by predicting the time until minimum separation is violated in the horizontal and vertical dimensions. The horizontal prediction is designated TH, the vertical, TV. TH and TV must be less than some threshold value for a controller alert, proximity, threat and resolution advisory flag to be set. In all situations, a proximity check is also performed in each of the two directions. This allows for identification of a hazardous situation even under circumstances where the predictions TH, TV are not appropriate.

A few comments concerning the formulae used in detection are pertinent.

1. The modification to the TH formula (true horizontal tau is the current horizontal separation divided by the negative of the time derivative of the current horizontal separation), DSQ, reduces the value of TH depending on the aircraft velocities.
It allows more warning time for faster aircraft closure than given by the unmodified formula.

2. The parameter MD2 is the predicted miss distance at the time of minimum separation. It is required that MD2 be within certain distances for controller alert and threat advisory initiation.

3. The third page of the Detect Task flow chart (Figure 7-2) refers to the multiplicity of an aircraft pair (MULT). This is defined as follows:

MULT = 2 if neither aircraft is in a conflict table.

= NAC + 1 if only one aircraft is in a conflict table, where NAC is the number of aircraft in that table.

= NAC if both aircraft are in the same conflict table.

= NAC(AC1) + NAC(AC2) if the aircraft are in separate conflict tables.

7.1.1 Resolution Advisory Initiation

The Detect Task can be viewed as having two main functions, determining if the situation requires a resolution advisory and determining if a controller alert is warranted. The latter is discussed in the next section.

The resolution initiation logic, provided by routines SCMDF and SIFRF, entails three essential stages: a horizontal tau check, with horizontal immediate range override; a vertical tau check, with vertical immediate separation override; and a vertical convergence/divergence filter. Basically, this filter inhibits resolution advisory initiation when an aircraft pair is projected to be at a vertical separation of at least ALTDP (system parameter) within a period TDP (system parameter) from current time. Resolution flags may also be set through the maneuvering target threat logic (SMTTF Routine), which is designed to provide additional protection to ATARS equipped aircraft from unequipped aircraft, provided certain flight geometry requirements are met. These are as follows: first, the aircraft must be flying essentially in parallel; and second, the target (i.e., unequipped) aircraft must not be in-trail of the subject aircraft, or vice versa. Additionally, the aircraft must be within specified horizontal and vertical separations. If these conditions are satisfied, the target aircraft turn status is tested in order to anticipate a potential turn into the subject aircraft. If so, the appropriate flags are set, and the normal sliding window logic is bypassed in the Master Resolution Task.

The sliding window logic is also overridden if a resolution flag is set due to proximity alone or the values of TH and TV are significantly below the threshold limits.

Besides the vertical convergence/divergence filter there is an additional method for resolution initiation to be preempted, through the zone types. If both aircraft are in a final approach zone 1 or 2 (see 7.1.4), no resolution advisory flags are set.

7.1.2 Controller Alert Initiation

Controller alert initiation logic resembles the resolution advisory determination function. Its purpose is entirely distinct, however. If one or both aircraft are in a controlled state, it is desired to inform the controller of a possible conflict situation before a resolution advisory is necessary. As such, the system parameters are less stringent in controller alert routines and to a certain extent the program logic reflects this.

Controller alert initiation logic, provided by SCAFLG, entails two of the three stages of resolution advisory logic, tau checks and proximity overrides. In addition SCAFLG will set the CAFLG if the aircraft are parallel, offset, within specified horizontal and vertical separations and one aircraft is turning towards the other (see CAMAN). In this case and in the case of proximity overrides the sliding window logic is bypassed, i.e., ICAFLG is set.

Preemption of controller alert occurs if the aircraft are in an encounter area type (ENAT) 1 or 2, which does not require a controller alert, or are both in an active zone. Regional dependent processing is discussed in Section 7.1.4.

7.1.3 Parameter Selection

The majority of the various thresholds that appear in the Detect Task and its routines depend on a number of criteria for their determination. Those parameters (or thresholds) that are not true constants are in general assigned in the routine SETPAR. First, the non-constant thresholds may depend on the control status of the aircraft in an encounter: controlled/controlled, controlled/ uncontrolled, or uncontrolled/uncontrolled. Additional specification may depend on area type of the encounter (1, 2, 3, 4), multiplicity of the encounter, and ATARS equipage. In the case of uncontrolled/uncontrolled encounters, specification may also rely on a computed index, UUIND, which is set in the routine SETPAR. Furthermore, certain tau thresholds are computed based on closing speed, and ultimately rely on the thresholds TCONV and TCONH provided by the routine PREPAR. A synopsis of all detection parameters may be found in Table 7-11,

together with an indication of the specification mode, be it a true constant (in which case the nominal parameter value is entered), a table look-up, or computed based on table look-up values.

Notes on the tables follow.

Table 7-4 - contains parameters used in routine PREPAR to calculate TCONH and TCONV. These are the tau thresholds in the horizontal and vertical sense which determine the look-ahead times for a controller alert. TCONH and TCONV are in turn used in SETPAR to calculate resolution and threat advisory message look-ahead time. In this way the controller is guaranteed knowledge of a possible aircraft conflict before or at worst simultaneously with ATARS display posting. Note that the desired threshold time, TWARN, is modified so that the time until separation criteria (ACONTH, RCONTH) are violated is represented and not the time until collision.

Table 7-5 - defines the proximity thresholds (as opposed to tau thresholds) which when violated will generate a controller alert. Desensitization of the ATARS detection logic occurs as these distances decrease for the smaller numbered area and zone type. MDCON2 is the threshold for predicted minimum miss distance, RCON2 and AFCON the thresholds for the present separation in each dimension.

Tables 7-6 through 7-8 - define the tau thresholds and immediate proximity thresholds for resolution advisory and threat advisory conditions. The intention is to guarantee (if time permits) the sequence of events as explained in Sections 2.2.1 - 2.2.3. For example, one aircraft is uncontrolled, the other controlled, both equipped. The threat advisory to both aircraft and the controller alert are posted at the same time, since the delay from controller alert time (the column labeled S) is 0 (zero) for TFPWI, TFIFR parameters. A resolution advisory to the uncontrolled aircraft occurs 15 seconds after controller alert (S column for TCMD parameter) and if no change in the situation occurs the resolution advisory to the controlled aircraft occurs 20 seconds later (S under TIFR parameter column). Of course the initiation times cannot be too large or small, hence the L and U columns.

The tabular settings can be modified under one condition - there is no delay giving a controlled aircraft resolution advisories if there is a large speed differential compared to the uncontrolled aircraft. The system parameter VRATC determines this condition.

Table 7-9 - defines the parameters used in the vertical divergence logic present in those routines which set a resolution advisory flag. Two sets of parameters exist, both aircraft uncontrolled (UCMDT)or at least one aircraft controlled (CCMDT). If the time to minimum separation violation is TVDP seconds, then the logic is applied. For aircraft more than ALTDP feet apart after TDP seconds, no resolution advisory flag is set.

7.1.4 Area Type and Zone Determination

As indicated previously, selection of thresholds may depend on the area type of an encounter, ENAT, determined in the routine SENAT. The encounter area type depends, in turn, on the individual aircraft area types, ACAT, which are determined in the SATAZ routine. This provides a means for desensitizing logic thresholds, with ENAT 4 being the most sensitive area, ENAT 1 being the least sensitive. Each ACAT area type 1 or 2 defines a horizontal parallelogram, type 1 encompassing the immediate vicinity of an airfield, and type 2 approach areas for each runway between specified altitudes. Area type 1 may, however, be further modified with "legs", or straight line segments that may be used to remove corners of the parallelogram. Type 3 is the balance of the airspace out to a range of RDIST (system parameter), beyond which the area type is 4 (see Table 7-10). SENAT defines the mapping of individual aircraft area types into the encounter area type.

The final approach zone status of arriving aircraft, FAZ, contained in the state vector is utilized in the Detect Task, the Terrain/ Airspace/Obstacle Avoidance Task as well as in the Master Resolution Task. Basically, the final approach zone is divided into two types, type 1 encompassing the airfield (and generally to a lower altitude than for area type 1), and type 2 encompassing a sloping rectangular region containing the normal approach path for each runway. In the type 2 zones, a table of active flags indicates the current status of each final approach zone 2.

The parameter FAZ can have the following values upon entry into the Detect Task.

FAZ = -1, not intialized for this aircraft,
must be set by Detect Task

FAZ = 0, aircraft is not in a final approach zone

FAZ = 1, aircraft is in a final approach zone 1

FAZ = 2, aircraft is in a final approach zone 2

The routine FAZSET, called when FAZ is not initialized, is the same routine used in the Terrain/Airspace/Obstacle Avoidance Task. If FAZ has the value 1 or 2 then the state vector parameter ZPRT has been initialized to the call letters of the airport associated with the final approach zone.

The area types define the area of desensitization for the controller alert function, the zones define the area for desensitization for the resolution advisory function. However, there is one important exception - zone 2. This region also defines where controller alerts generated by prediction (tau tests) are to be inhibited. The proximity tests are never inhibited. Appropriate definition of this area will prevent nuisance alerts in parallel approach zones and converging approach zones. Zone 2 should always be encompassed by area type 1 and/or 2. For the prevention function to be applicable both aircraft must be in a zone 2 region (not necessarily the same) associated with the same airport.

7.1.5 Detect/Executive Interface

The detection logic requires the following parameters from both of the state vectors associated with the aircraft pair: X, Y, Z, XD, YD, ZD, VSQ, TURN, CTPTR. If available in the state vector, the Detect Task will use FAZ and ZPRT. If not available detect will determine FAZ and ZPRT, inserting them into the state vector. From the conflict table, if it exists (CTPTR not null) detect requires NAC, BIC. From the Coarse Screen Processing Task, the parameter, TLA, is required. It is the executive program's responsibility to assemble these needed variables and guarantee their existence upon calling the Detect Task.

On completion of the Detect Task all eight flags have been initialized and appropriately set: PWIFLG, FPWFLG, FPIFLG, CMDFLG, IFRFLG, CAFLG, ICAFLG, MTTFLG. If the flags indicate any type of ATARS advisory message is to be posted or a controller alert is required, then the Detect Task also guarantees a value for ALT, DOT, ENAT, MD2, RANGE2, TCMDV, TCMDH, TH, TV.

It is the executive program's function to disburse the Detect Task output as necessary. Specifically:

1. No resolution advisories (CMDFLG, IFRFLG not set) but proximity and/or threat advisories are required (PWIFLG,

FPWFLG, FPIFLG set), an entry is created for the Proximity Encounter List. A controller alert may or may not be required. Number 3 below may also apply.

2. A resolution advisory (CMDFLG or IFRFLG set) or a controller alert (CAFLG or ICAFLG set) is required, an entry is created from the Detect Task output and placed on the Resolution Encounter List.

3. CMDFLG and IFRFLG flags zero and a conflict pair record exists for the aircraft, an entry is placed on the Resolution Deletion Encounter List.

4. All flags zero and no conflict pair record exists, no action is taken.

Besides the three encounter lists mentioned, there are the Delayed Resolution Encounter List and the Normal Resolution Encounter List. Both of these lists are formed by the Seam Pair Task from the Resolution Advisory List as generated by the Detect Task. The entry format is standard for all five lists. Table 7-12 defines this entry structure.

7.2 Seam Pair Task

This task selects the correct disposition of each pair found on the Resolution Encounter List. Such pairs either have CMDFLG set, with other flags in any condition, or have only CAFLG set (and not CMDFLG, FPWFLG, FPIFLG, or PWIFLG). The Seam Pair Task (Figure 7-16) classifies each pair in one of four groups:

1. Pairs already being resolved by another ATARS site.

2. Pairs previously resolved by another ATARS site, but now in "handoff" condition. (Caution: This term refers only to ATARS responsibility and has nothing to do with ATC control or ATC handoff.)

3. Pairs already being resolved by own-site.

4. Pairs not yet being resolved.

If a pair falls into group (2) or (4), a priority test is performed to determine own-site's eligibility to resolve the pair. When one or both aircraft are ATCRBS, own-site assumes it has priority. If both are DABS, then own-site has priority if own ATARS site ID bit is the highest bit appearing in both GEOG1 and GEOG2.

If own-site does not have priority in groups (2) and (4) or the pair is in group (1), the pair is put onto the proximity encounter list (except when only CAFLG was set) for traffic advisory processing. This service may be permitted, even if own-site does not have resolution responsibility for this pair.

The remainder of the task is performed when own-site has priority, or was already resolving the pair. If CAFLG is set, the pair is placed on the controller alert buffer. Ir CMDFLG is not set, or if the pair is ATCRBS-ATCRBS, resolution will not be performed.

If a pair record already exists, the PWISF flag is set to inhibit pair removal (Section 13.) since this pair is receiving resolution processing this scan. The pair record sector identification is updated here. If ATSID indicated a "handoff" (group 2) own ID is put into ATSID. For groups (2) and (4), a message is sent to any adjacent sites also providing service to either aircraft. This message announces that own-site is resolving this pair. It should be sent promptly since ATCRBS-DABS pairs are assigned to sites in a first-come first-serve manner. At this point it is necessary to decide whether resolution processing can proceed immediately, or whether the resolution processing must be delayed until conflict tables have been received from adjacent ATARS sites. Resolution of a pair of aircraft which could in any way be influenced by actions taken by neighboring ATARS sites must be delayed until replies are received from all neighboring ATARS sites serving either aircraft. In no case does this delay extend beyond a cutoff time determined by the executive.

Resolution is delayed if:

1. The pair is already represented in a seam conflict table and the local ATARS is responsible for that pair, or

2. the pair was not previously in conflict but at least one of the aircraft is in an ATARS seam or is in a seam conflict table.

In these situations, the pair is placed on the Delayed Resolution List; otherwise, the pair is placed on the Normal Resolution List.

8. DATA LINK MESSAGE PRE-PROCESSING TASK

The Data Link Message Pre-processing Task creates, updates, and deletes entries on a list maintained for each subject aircraft in a conflict. This list, called the Proximity Warning Indicator List (PWILST) is linked to the state vector of the subject aircraft and contains all data on aircraft which are in conflict with the subject aircraft. This list is initialized for the conflict, is updated during the conflict either by addition of a new aircraft or a change in the conflict status, and is deleted when the subject aircraft is no longer in conflict or has left the ATARS service area. This list is processed by the Data Link Message Construction Task (discussed in Section 14) to generate Proximity, Threat, or Resolution Advisory Messages for the subject aircraft.

8.1 PWILST List Structure

Each object aircraft in conflict with the subject aircraft has entries on the list. Each entry contains a header segment followed by a varying length message segment. Figure 8-1 diagrams a portion of the subject aircraft state vector, the conflict table, pair record and the PWILST. Figure 8-2 shows further details of the PWILST structure. Page 1 of Figure 8-2 shows each field in the PWILST header. The header fields are used internally by programs that process the PWILST. Page 2 of Figure 8-2 shows the types of message segments that may follow the header segment. Each segment is named by encounter (conflict) type. A Proximity Segment contains data that is generated for an encounter which is at the warning level. A Threat Segment contains data generated for an encounter at the threatening level, and a Resolution Segment contains data generated for an encounter which is very serious and requires resolution.

8.2 PWILST Message Data

The Proximity Segment, shown diagrammed in Figure 8-3, contains three types of data: position data, start/end data, and supplementary proximate data. Tables 8-1 through 8-9 provide further details on each type of data required in the Proximity Segment.

Four types of data are required in the Threat Segment shown diagrammed in Figure 8-4: basic threat data, position data, start threat data, and end data. Tables 8-10 through 8-14 provide further details on each new type of data required in the Threat Segment.

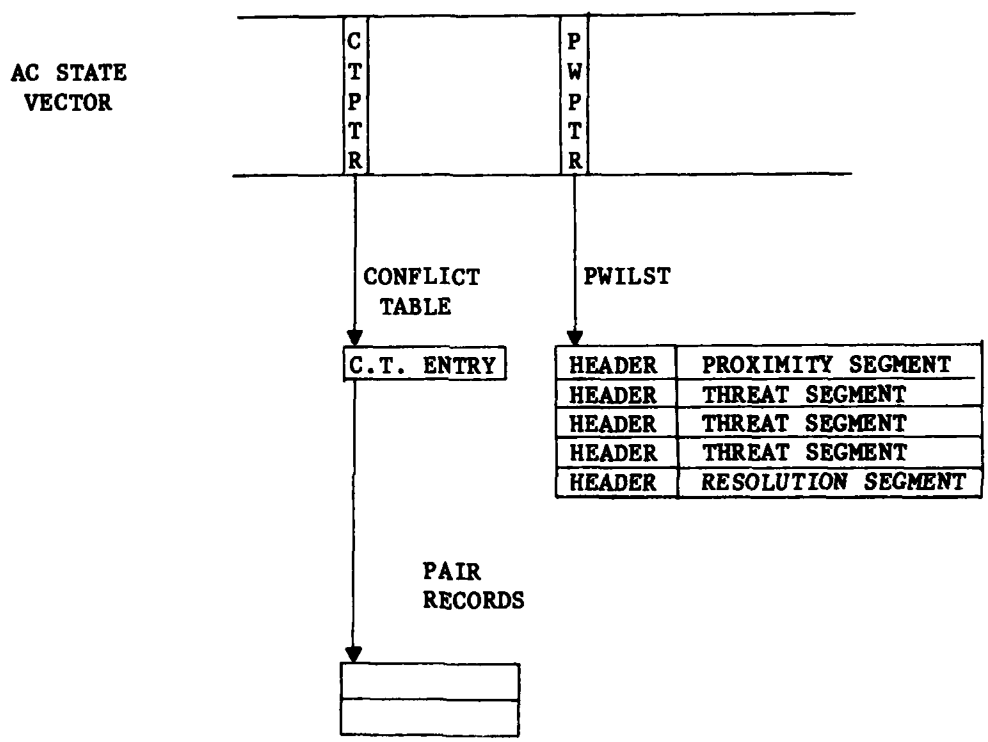


FIGURE 8-1
LISTS LINKED TO THE STATE VECTOR

PWPTR in AC State Vector

HEADER	NXTPWI	-	Pointer to next PWI entry
	ACID	-	Identification of aircraft causing the advisory. (Pointer to state vector)
	PWINO	-	Unique number 0 to 7. Not a ranking. Called "Track No." in message formats
FIELDS	TYPE	-	Proximity (P); threat (T); threat without resolution (TN); threat with resolution (TR); resolution (R); or end encounter (E)
	PMCCTR	-	Previous most critical encounter pointer
	Rank Data (RNKDTA)	-	Measure to implement ranking. Horizontal tau and weighted separation if TYPE = threat (T, TN, or TR). Weighted separation if TYPE = proximity (P)
	Start Flag (STFLG)	-	Indicates new PWI entry requiring start message unless PWINO is a replacement
	End Flag (ENDFLG)	-	Indicates entry to be deleted after end message sent successfully
	NEWFLG	-	Indicates new PWI entry requiring a track number

FIGURE 8-2
PWILST STRUCTURE (Page 1 of 2)

MESSAGE FIELD	PROXIMITY SEGMENT THREAT SEGMENT RESOLUTION SEGMENT	- All data required for messages

FIGURE 8-2
PWILST STRUCTURE (Page 2 of 2)

PROXIMITY SEGMENT	POSITION DATA	-	Shown in expanded form in Table 8-1
	START/END DATA	-	Shown in expanded form in Table 8-5
	SUPPLEMENTARY PROXIMATE (PROX) DATA	-	Shown in expanded form in Table 8-7

FIGURE 8-3
PWILST PROXIMITY SEGMENT

TABLE 8-1

POSITION DATA

FIELD	BITS	INTERPRETATION
Clock Bearing (CB)	4	1 o'clock (0001) through 12 o'clock (1100)
Fine Bearing (FB)	3	Bearing to target = ((CB) - 1/2) * 30° + (FB) * 3.75°
Altitude Zone	2	Bit 1: proximate or threat aircraft above (1) or below (0) Bit 2: proximate or threat aircraft co-altitude (1) or not (0)
Relative Altitude (RA)	3	If co-altitude (0 to 500'): = (RA) * 100'. If not co-altitude (600' to 2000'): = (RA) * 200' + 600'
Range (R)	6	0 to 12.6 nmi = (R) * 0.2 nmi. If .GE. 12.6 display 12.6
Coarse Heading (CH)	3	N(000), NE(001), E(010), SE(011) etc. (See Table 8-7 for Fine Heading)
ATC Control	1	Controlled (1), uncontrolled (0)
ATARS Equipped	1	ATARS equipped (1) or not (0)
Most Critical Flag	1	Most critical advisory (1) or not (0)
TOTAL	24	

TABLE 8-2

SOURCE OF POSITION DATA

FIELD	SOURCE
Clock Bearing (CB)	Table 8-3, Equation I
Fine Bearing (FB)	Table 8-3, Equation II
Altitude Zone	Table 8-3, Equation III
Relative Altitude (RA)	Table 8-3, Equation IV
Range (R)	Table 8-3, Equation V
Coarse Heading (CH)	Table 8-3, Equation VI
ATC Control	State Vector
ATARS Equipped	State Vector
Most Critical Flag	Figure 14-4, Compute Criticality Routine

TABLE 8-3

POSITION DATA FIELDS

Notes for Table 8-3 through Table 8-23:

1. All angles expressed in degrees.
2. Logic expressions equal 1 if true, 0 if false.
3. INT ( ) is the integer part function. This is rounded (except where noted) by adding .5 before taking the integer part.
4. State vector variables ending in 1 apply to own aircraft, those ending in 2 apply to other aircraft.
5. X1, Y1 Position of aircraft 1
6. XD1, YD1 Velocity of aircraft 1

BEARING = ARC COS (A/SQRT ((RANGE2)*($XD1^2$ + $YD1^2$))) Correct for proper quadrant.

RX = X2 - X1   A = RX*XD1 + RY*YD1

RY = Y2 - Y1   RANGE2 = $RX^2 + RY^2$

I   Clock Bearing (CB) = INT ((BEARING)/30)

Change CB = 0 to CB = 12 (See Table 8-4 for Clock Bearing corresponding to bearing angles)

II   Fine Bearing (FB) = INT ((BEARING - (CB - 1/2) * 30^o)/3.75^o)

Note: this value is a positive increment to the low end of CB sector.

III   Altitude Zone: Bit 1 = SIGN (RZ) RZ = Z2 - Z1   SIGN (RZ)=1 if RZ .GE. 0)
Bit 2 = ABS(RZ) .LE. PWIZ   SIGN (RZ)=0 if RZ .LT. 0)

IV   Relative Altitude (RA) = INT ((ABS(RZ) .LE. PWIZ) * ABS(RZ)/100 (ft)
+ (ABS(RZ) .GT. PWIZ) * (ABS(RZ)-600)/200 (ft))

V   Range (R) = INT(SQRT ($RX^2 + RY^2 + RZ^2$)/0.2 (nmi))

VI   Coarse Heading (CH) = INT ((HEADING)/45)

HEADING = ARC COT (YD2/XD2) Correct for proper quadrant.

Change CH = 8 to CH = 0

VII   ATC Control = CUNC2

VIII   ATARS Equipped = ATSEQ2

TABLE 8-4

CLOCK BEARING

Let phi be the bearing of aircraft 2 from aircraft 1 measured positive clockwise from the track heading of aircraft 1 and expressed as an angle between 0 and 360°. Then the clock bearing is:

LOWER LIMIT .LE. PHI (DEGREES) .LT. UPPER LIMIT	CLOCK BEARING
345 - 15	12
15 - 45	1
45 - 75	2
75 - 105	3
105 - 135	4
135 - 165	5
165 - 195	6
195 - 225	7
225 - 255	8
255 - 285	9
285 - 315	10
315 - 345	11

TABLE 8-5

START/END DATA

FIELD	BITS	INTERPRETATION
Sensor Termination	1	Sensor reporting encounter terminated (1) or not (0)
Velocity (V)	7	0 to 1,270 kts = (V) * 10 kts
Track Number	3	0 through 7
Aircraft Abbreviated Data	13	Currently undefined
TOTAL	24	

TABLE 8-6

SOURCE OF START/END DATA

FIELD	SOURCE
Sensor Termination	Compute Own/End Data Routine
Velocity (V)	Table 8-9, Equation II
Track No.	Compute Criticality Routine
Aircraft Abbreviated Data	ATC Computer

TABLE 8-7

SUPPLEMENTARY PROXIMATE DATA

FIELD	BITS	INTERPRETATION
Track Number	3	0 through 7
Fine Heading (FH)	4	Heading = ((CH) - 1/2) * 45° + (FH) * 2.8125° Note: (CH is contained in position data)
Velocity (V)	7	0 to 1,270 kts = (V) * 10 kts
Turn Type of of Threat	3	Bit 1: straight (0) or turn (1); Bit 2: right (1) or left (0) and Bit 3: strong (1) or weak (0)
Vertical Speed of Threat (VS)	6	0 to 6200 fpm = (VS) * 200 fpm (Signed two's complement with positive upward)
Spare	1	Set = 0
TOTAL	24	

TABLE 8-8

SOURCE OF SUPPLEMENTARY PROXIMATE DATA

FIELD	SOURCE
Track Number	Figure 14-4, Compute Criticality Routine
Fine Heading (FH)	Table 8-9, Equation I Table 8-3, Equation VI
Velocity (V)	Table 8-9, Equation II
Turn Type of Threat	Table 8-9, Equation III
Vertical Speed of Threat (VS)	Table 8-9, Equation IV

TABLE 8-9

SUPPLEMENTARY PROXIMATE DATA FIELDS

I Fine Heading = INT ((HEADING - (CH - 1/2)*45°)/2.8125°)

II Velocity (V) = INT (SQRT (VSQ2)/10 kts)

III Turn Type - see table below

	TURN VALUE	TURN TYPE FIELD		
Strong left	-2	1	0	1
Weak left	-1	1	0	0
Strong right	+2	1	1	1
Weak right	+1	1	1	0
All other		0	0	0

IV Vertical Speed (VS) = INT (ZD2/200) Note: ZD2 in ft/min

THREAT SEGMENT	BASIC THREAT DATA	-	Shown in expanded form in Table 8-10
	POSITION DATA	-	Shown in expanded form in Table 8-1 (Same as for Proximity Segment)
	START THREAT DATA	-	Shown in expanded form in Table 8-13
	END DATA	-	Shown in expanded form in Table 8-5
		-	(Same as for Proximity Segment)

FIGURE 8-4
PWILST THREAT SEGMENT

TABLE 8-10

BASIC THREAT DATA

FIELD	BITS	INTERPRETATION
Predicted Horizontal Miss Distance (PMD)	3	0 to 1.4 nmi = (PMD) * 0.2 nmi
Vertical Speed of Threat (VS)	6	0 to 6,200 fpm = (VS) * 200 fpm (two's complement with positive upward)
Relative Altitude Extension (RAE) (Note: RAE = 0 if RA .LE. 2000 ft)	3	0 to 3500' = (RAE) * 500' (Note: total relative altitude = relative altitude (from position data) + relative altitude extension; therefore, RAE = 111 implies total relative altitude .GE. 5250')
Fine Heading (FH)	4	Heading = ((CH) - 1/2) * 45° + (FH) * 2.8125° (Note: CH is contained in position data)
Turn Type of Threat	3	Bit 1: straight (0) or turn (1); Bit 2: right (1) or left (0); Bit 3: strong (1) or weak (0)
Track No	3	0 through 7
First Time Threat Data Transmitted	1	First time (1) or not (0). Set = 1 if Start Threat to Threat transition. Set = 1 if 1st Time Threat to Threat update and 1st Time Threat not delivered successfully. Set = 0 otherwise
Resolution Bit	1	Threat aircraft is receiving resolution advisory (1) or not (0) from an ATARS site (shown by ATSID in the pair record = local site ID, other ATARS site ID, or handoff and a maneuver exists in the pair record for the threat aircraft)
TOTAL	24	

TABLE 8-11

SOURCE OF BASIC THREAT DATA

FIELD	SOURCE
Predicted Horizontal Miss Distance (PMD)	Table 8-12, Equation I
Vertical Speed of Threat (VS)	Table 8-12, Equation II
Relative Altitude Extension (RAE)	Table 8-12, Equation III Table 8-3, Equation IV
Fine Heading (FH)	Table 8-9, Equation I Table 8-3, Equation VI
Turn Type of Threat	Table 8-12, Equation V
Track No	Compute Criticality Routine
First Time Threat Data Transmitted	Data Link Message Pre-processing Task
Resolution Bit	Data Link Message Pre-processing Task

TABLE 8-12

BASIC THREAT DATA FIELDS

RX = X2 - X1

RY = Y2 - Y1

$RANGE2 = RX^2 + RY^2$

DOT = RX*VRX + RY*VRY

VRX = XD2 - XD1

VRY = YD2 - YD1

$VR2 = VRX^2 + VRY^2$

If VR2 .LT. VMDTH then MD2 = RANGE2

IF VR2 .GE. VMDTH the $MD2 = (RX*VRY - RY*VRX)^2/VR2$

I Predicted Horizontal Miss Distance

= INT (SQRT (RANGE2)/0.2 nmi) (if DOT .GE. 0)

= INT (SQRT (MD2)/0.2nmi) (if DOT .LT. 0)

II Vertical Speed (VS) = INT (ZD2/200) Note: ZD2 in ft/min

III Relative Altitude Extension (RAE) used only if RA .GT. 2000 ft
=INT (ABS (RZ - 2000 ft) /500 ft)(if RA .LE. 2000 ft, RAE = 0)

IV Fine Heading (FH) - Same as supplementary proximate data.

V Turn Type of Threat - see table below

	TURN VALUE	TURN TYPE FIELD		
Strong left	-2	1	0	1
Weak left	-1	1	0	0
Strong right	+2	1	1	1
Weak right	+1	1	1	0
All other		0	0	0

TABLE 8-13

START THREAT DATA

FIELD	BITS	INTERPRETATION
Continuation	1	(1) Track number exists (0) New track number
Velocity (V)	7	0 to 1,270 kts = (V) * 10 kts
Track No.	3	0 through 7
Aircraft Abbreviated Data	13	Set = 0
TOTAL	24	

TABLE 8-14

SOURCE OF START THREAT DATA

FIELD	SOURCE
Continuation	Compute Criticality Routine
Velocity (V)	Table 8-9, Equation II
Track No.	Compute Criticality Routine
Aircraft Abbreviated Data	ATC Computer

The Resolution Segment is shown in Figure 8-5. This segment contains either DABS resolution data or ATCRBS resolution data and ATCRBS track block data. This is the only segment type which does not require all the data types shown in the segment diagram. Tables 8-15 through 8-23 describe the resolution data in further detail.

8.3 PWILST Management

The Data Link Message Pre-processing Task manages the PWILST by determining the current encounter type, searching the subject aircraft's PWILST for an entry which is keyed by the object aircraft's identification number, and performing standard initialization, update or deletion for the PWILST entries. Figure 8-6 shows an example of PWILST management where the subject aircraft is in an encounter with several aircraft and the program is currently searching for entry "A".

8.3.1 Encounter Type Determination

The encounter type is determined first from the status of flags and second from site priority and DABS sensor status. When flag settings determine that the encounter is a resolution type and the site has priority, a Resolution Segment is generated. When flag settings determine that the encounter is at the threat or warning level and the sensor is primary, Threat or Proximity Segments are generated.

When an encounter is within the site boundary where ATARS provides full resolution services, the site has priority and the sensor is primary. In this area, all segment types may be generated to provide all ATARS messages. Outside this boundary where overlapping coverage from several sites creates a seam, some ATARS messages are suppressed and the segment types supporting these messages are not created or, if they already exist, they are deleted. After the flag status, site priority, and sensor status is determined, six encounter types for new encounters may exist.

1. Encounter type "TR" (threat and resolution) means that the appropriate conditions exist for generation of a Threat Segment and a Resolution Segment.

2. Encounter type "R" (resolution only) means that a "TR" encounter type would normally exist, but since the sensor is not primary, the Threat Segment of the normal threat/resolution pair is suppressed.

RESOLUTION SEGMENT		
	DABS RESOLUTION DATA	- Shown in expanded form in Table 8-15
	ATCRBS RESOLUTION DATA	- Shown in expanded form in Table 8-18
	ATCRBS TRACK BLOCK DATA	- Shown in expanded form in Table 8-20

FIGURE 8-5
PWILST RESOLUTION SEGMENT

AD-A094 195 MITRE CORP MCLEAN VA METREK DIV F/G 1/5
AUTOMATIC TRAFFIC ADVISORY AND RESOLUTION SERVICE (ATARS) MULTI--ETC(U)
OCT 80 R H LENTZ, W D LOVE, N S MALTHOUSE DOT-FA80WA-4370
UNCLASSIFIED MTR-80W00100-REV-1 FAA-RD-80-3-REV-1 NL

4 OF 6
AD A
094 195

4 OF

AD A
094195

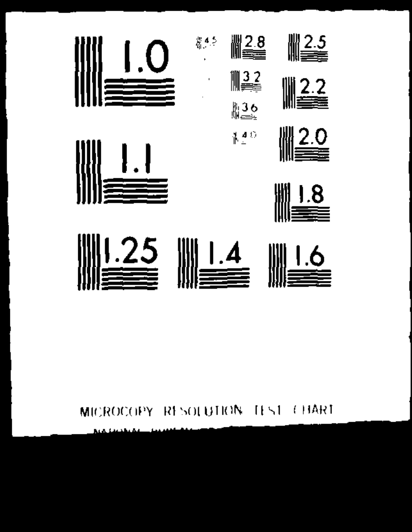


TABLE 8-15

DABS RESOLUTION DATA

FIELD	BITS	INTERPRETATION
DABS ID	24	DABS ID
Resolution Advisory	10	(See Figure 8-17)
VSL Value	2	(See Figure 8-17)
First Time Transmitted	1	First time (1) or not (0). Set = 1 if new resolution advisory (STFLG set). Set = 1 if update and new resolution advisory .NE. last successfully delivered resolution advisory. Set to 0 otherwise
Track #	3	0 through 7
Track # Unknown	1	Set = 1 when no track # exists in the conflict table indicating that multi-site coordination has not occurred over groundlines. Set = 0 otherwise
Handoff	1	Set = handoff bit in ATSID indicating that aircraft has left ATARS coverage zone
Spares	6	(Set = 0)
TOTAL	48	

TABLE 8-16

SOURCE OF DABS RESOLUTION DATA

FIELD	SOURCE
DABS ID	State Vector
Resolution Advisory	Conflict Table and Table 8-17
VSL Value	Conflict Table and Table 8-17
First Time Transmitted	Data Link Message Pre-processing Task
Track # and Track # Unknown	Compute Criticality Routine
Handoff Bit	Pair Record (ATSID)

TABLE 8-17

CODING FOR RESOLUTION ADVISORY AND VSL DATA FIELD

BIT #	RESOLUTION ADVISORY FIELD	
1	0 = No horizontal maneuver	1 = Horizontal maneuver
2	0 = Horizontal is positive	1 = Horizontal is negative
3	0 = Sense is turn left or don't turn right	1 = Sense is turn right or don't turn left
4	0 = No vertical maneuver	1 = Vertical maneuver
5	0 = Vertical is positive	1 = Vertical is negative or VSL according to bit 6
6	0 = Negative	1 = VSL
7	0 = Sense is climb or don't descend	1 = Sense is descend or don't climb
8	0 = Single threat	1 = Multiple threats (MT bit)
9	0 = Normal condition	1 = Coordination failed (FAIL bit)
10	0 = Maneuver for display	1 = Complement flag; no display

BIT #	VSL FIELD (APPLIES WHEN BIT 6 ABOVE = 1)	
1	0 = Limit to 500 ft/min	1 = Bit 2 determines
2	0 = Limit to 1000 ft/min if bit 1 = 1	1 = Limit to 2000 ft/min if bit 1 = 1

TABLE 8-18

ATCRBS RESOLUTION DATA*

FIELD	BITS	INTERPRETATION
ATCRBS ID	13	ATCRBS ID
ATCRBS ID Availability	1	Set = 1 when ATCRBS ID is available. Set = 0 otherwise
Resolution Advisory	10	(See Figure 8-17)
VSL Value	2	(See Figure 8-17)
First Time Transmitted	1	First time (1) or not (0). Set = 1 if new resolution advisory (STFLG set). Set = 1 if update and new resolution advisory .NE. last successfully delivered resolution advisory
Track #	3	0 through 7
Track # Unknown	1	Set = 1 when no track # exists in the conflict table indicating that multi-site coordination has not occurred over ground lines. Set = 0 otherwise
Handoff	1	Set = handoff bit in ATSID indicating that aircraft has left ATARS coverage zone
Spares	16	(Set = 0)
TOTAL	48	

* Requires calculation of ATCRBS Track Block Data

TABLE 8-19

SOURCE OF ATCRBS RESOLUTION DATA

FIELD	SOURCE
ATCRBS ID	State Vector (CODE1)
ATCRBS ID Availability	State Vector
Resolution Advisory	Conflict Table and Table 8-17
VSL Value	Conflict Table and Table 8-17
First Time Transmitted	Data Link Message Pre-processing Task
Track # and Track # Unknown	Compute Criticality Routine
Handoff Bit	Pair Record (ATSID)

TABLE 8-20

ATCRBS TRACK BLOCK DATA

FIELD	BITS	INTERPRETATION
Range to ATCRBS Threat (R)	8	Positive binary LSB = 0.125 nmi. Largest is 31.875 nmi also used for greater range
Range Rate to ATCRBS Threat (RD)	7	Two's complement LSB = 20 kts. Largest value is ± 1260 kts
Bearing to ATCRBS Threat (THETA)	8	Positive binary LSB = 1.406250°. Use "bearing" intermediate calculation from position data
Bearing Rate to ATCRBS Threat (THDOT)	7	Two's complement LSB = 0.5 deg/sec. Largest value is ± 31.5 deg/sec
Altitude of ATCRBS Threat (RZ)	10	Positive binary LSB = 100 ft. Largest value is 102,300 ft
Altitude Rate of ATCRBS Threat (ZD)	7	Two's complement LSB = 2 ft/sec. Largest value is ± 126 ft/sec
Spare	1	Set to zero
TOTAL	48	

TABLE 8-21

SOURCE OF ATCRBS TRACK BLOCK DATA

FIELD	SOURCE
Range to ATCRBS Threat (R)	Table 8-22, Equation I
Range Rate to ATCRBS Threat (RD)	Table 8-22, Equation II
Bearing to ATCRBS Threat (THETA)	Table 8-3, BEARING
Bearing Rate to ATCRBS Threat (THDOT)	Table 8-22, Equation III
Altitude of ATCRBS Threat (RZ)	State Vector
Altitude Rate of ATCRBS Threat (ZD)	Table 8-22, Equation IV

TABLE 8-22

ATCRBS TRACK BLOCK DATA FIELDS

I	Range to ATCRBS Threat (R)	=	SQRT (RANGE2 + RZ^2)
	VRZ = ZD2 - ZD1		
II	Range Rate to ATCRBS Threat (RD)	=	(DOT + RZ * VRZ)/R
III	Bearing Rate to ATCRBS Threat (THDOT)	=	See Table 8-23
IV	Altitude Rate of ATCRBS Threat (ZD)	=	ZD2 ft/min * 1 min/60 sec

TABLE 8-23

COMPUTATION OF BEARING RATE TO ATCRBS THREAT

Bearing Rate of Threat =

(Velocity of threat * SIN (Bearing of own to threat)
+ Velocity of own * SIN (Bearing of threat))/range to threat
- own turn rate

$$\text{BEARING RATE 1} = (\text{SQRT}(\text{XD2}^2 + \text{YD2}^2) * \text{SIN (BEARING 2)} + \text{SQRT}(\text{XD1}^2 + \text{YD1}^2) * \text{SIN (BEARING 1))/SQRT}(\text{RANGE}^2) - \text{TURNRT 1}$$

$$\text{BEARING 1} = \text{ARC COS (A/SQRT}(\text{RANGE}^2 * (\text{XD1}^2 + \text{YD1}^2)$$ corrected for proper quadrant

A = (X2 - X1) * XD1 + (Y2 - Y1) * YD1

BEARING 1 = Bearing of AC2 seen from AC1
BEARING 2 = Bearing of AC1 seen from AC2
BEARING RATE 1 = Bearing rate of AC2 seen from AC1
TURNRT 1 = Turn rate of AC1

Note: Formula for bearing is in Table 8-3

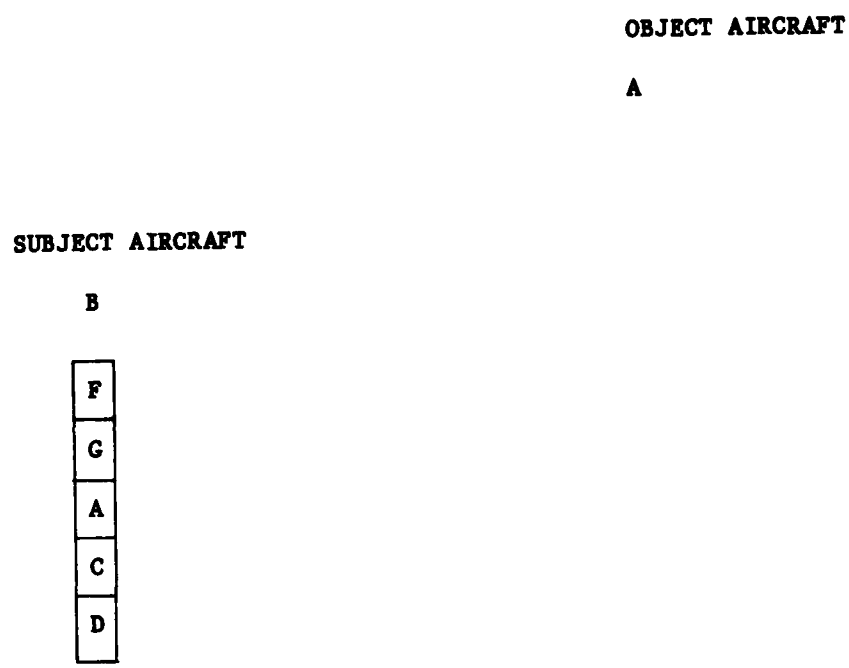


FIGURE 8-6
SUBJECT AIRCRAFT'S PWILST SEARCHED FOR ENTRY "A"

3. Encounter type "TN" (threat and no resolution) means that a "TR" encounter type would normally exist, but since the site does not have priority, the Resolution Segment of the normal threat/resolution pair is suppressed.

4. Encounter type "T" (threat) means that the appropriate conditions exist for generation of a Threat Segment.

5. Encounter type "P" (proximity) means that a Proximity Segment is to be generated.

6. Encounter type "None" means that the site is not responsible for resolution services and all segments supporting the advisories are suppressed.

Figure 8-7 provides an example of the types of messages generated for various primary/priority states. As can be seen from this figure, when an ATARS site constructs messages for an aircraft in the seam, the other ATARS site which shares that seam will also construct messages for that aircraft. The types of messages that are generated depend on the site priority in relation to the subject aircraft and the status of the DABS sensor. When the site has priority, resolution advisories are generated. When the DABS sensor is primary, proximity and threat advisories are generated.

The tests in combinations shown below determine the message types that will be uplinked when resolution advisories, threat advisories, and proximity advisories would normally all exist.

1. All advisory types are uplinked if

   a. ATSID = local ID (site has priority) and
   b. the sensor is primary.

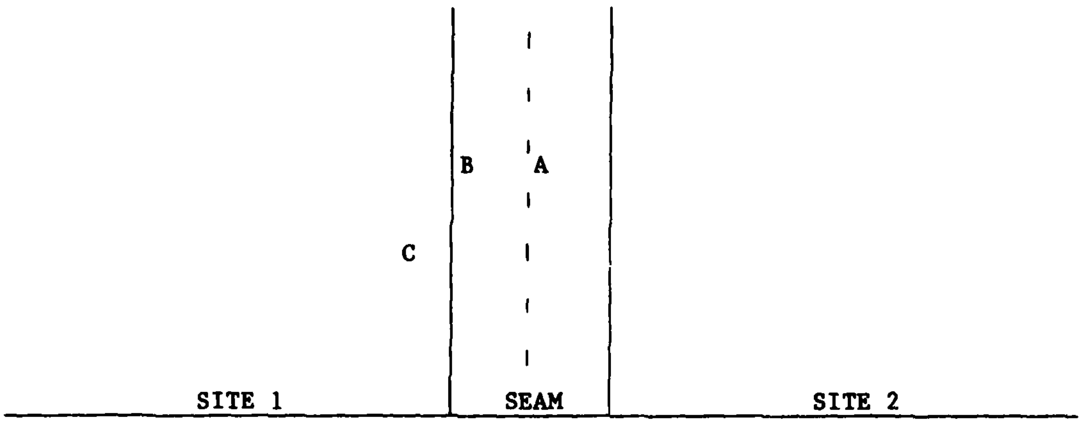
2. Proximity and threat advisories <u>only</u> are uplinked if

   a. ATSID is not equal to local ID (site has low priority) and
   b. the sensor is primary.

3. No advisories are uplinked (site is not responsible) if

   a. ATSID is not equal to local ID (site has low priority) and
   b. the sensor is not primary.

4. Resolution advisories only are uplinked if



Site 1 is primary for B, C and has priority for B, C pair	Site 2 is primary for A and has priority for A, B pair
Site 1 sends resolution advisories to B due to C	Site 2 sends resolution advisories to B due to A
Site 1 sends resolution advisories to C due to B	Site 2 sends resolution advisories to A due to B
Site 1 also sends threats and proximities to C due to B, to B due to C, and B due to A	Site 2 also sends threats and proximities to A due to B, but does not send proximities and threats to B due to A

FIGURE 8-7
EXAMPLE SHOWING SITE RESPONSIBILITY

a. ATSID = local ID and
b. the sensor is not primary.

8.3.2 PWILST Initialization, Update, Deletion

Entries in the PWILST from the previous radar cycle are sorted by encounter type. When new data for an encounter pair is processed, all entries must be searched for a match because new encounter types may not be related to the last encounter type in a predictable way.

To process new data, the PWILST is searched and entries are added if new, or updated if the entry already exists. For new entries, the header is initialized by setting the Start Flag (STFLG), setting the New Entry Flag (NEWFLG), setting the Encounter Type (TYPE), and resetting the End Flag (ENDFLG). The PWI Number (PWINO) field is not updated at this time. For updated entries, STFLG is reset for successfully delivered start encounter messages, the new TYPE is set, and the ENDFLG is reset. After the header fields are entered, all data required for the message segments is calculated. The initialization/ update cycle is completed in the Data Link Message Construction Task by assigning PWINO and setting ENDFLG as each message is constructed.

PWILST entries may be deleted when site priority changes or DABS sensor status changes. When this occurs, the segment is deleted and former messages time out in the aircraft. The deletion cycle is completed in the Data Link Message Construction Task by deleting Resolution Segments when the aircraft has flown outside ATARS coverage (allowing messages to time out), by sending end resolution messages when the Resolution Segment is not updated, and by either deleting Threat and Proximity Segments (when their numbers are needed for new entries) or sending end encounter messages when Threat Segments or Proximity Segments are not updated.

Further details of the Data Link Message Pre-processing Task are shown in the detailed flow charts presented in Figures 8-8 through 8-12. Further details of the Data Link Message Construction Task are discussed in Section 14.

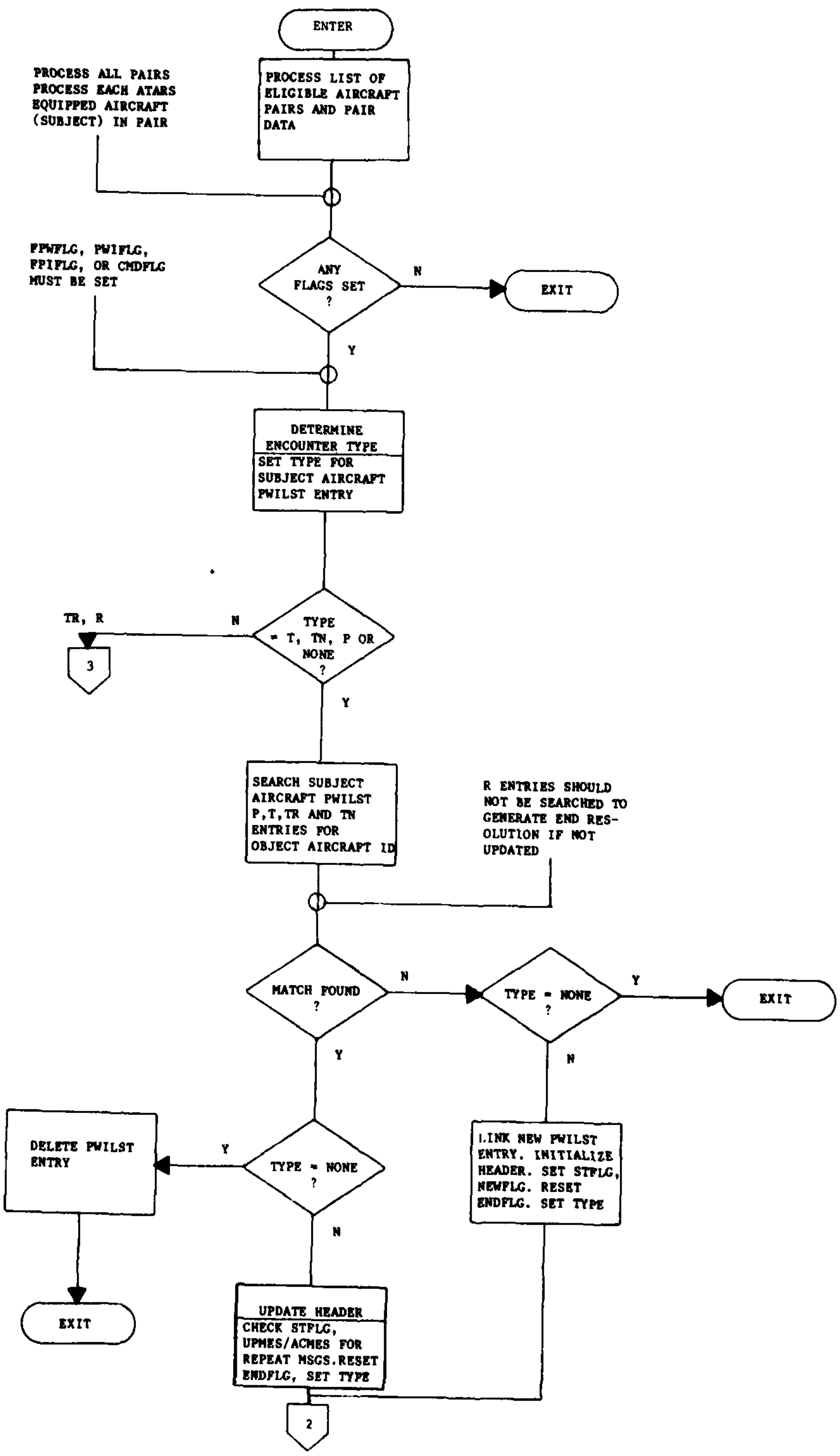


FIGURE 8-8
DATA LINK MESSAGE PRE-PROCESSING TASK (Page 1 of 4)

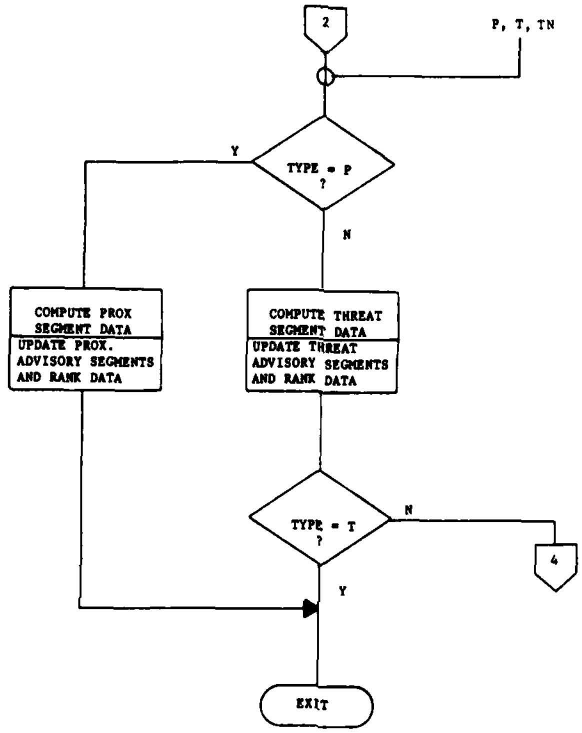


FIGURE 8-8
DATA LINK MESSAGE PRE-PROCESSING TASK (Page 2 of 4)

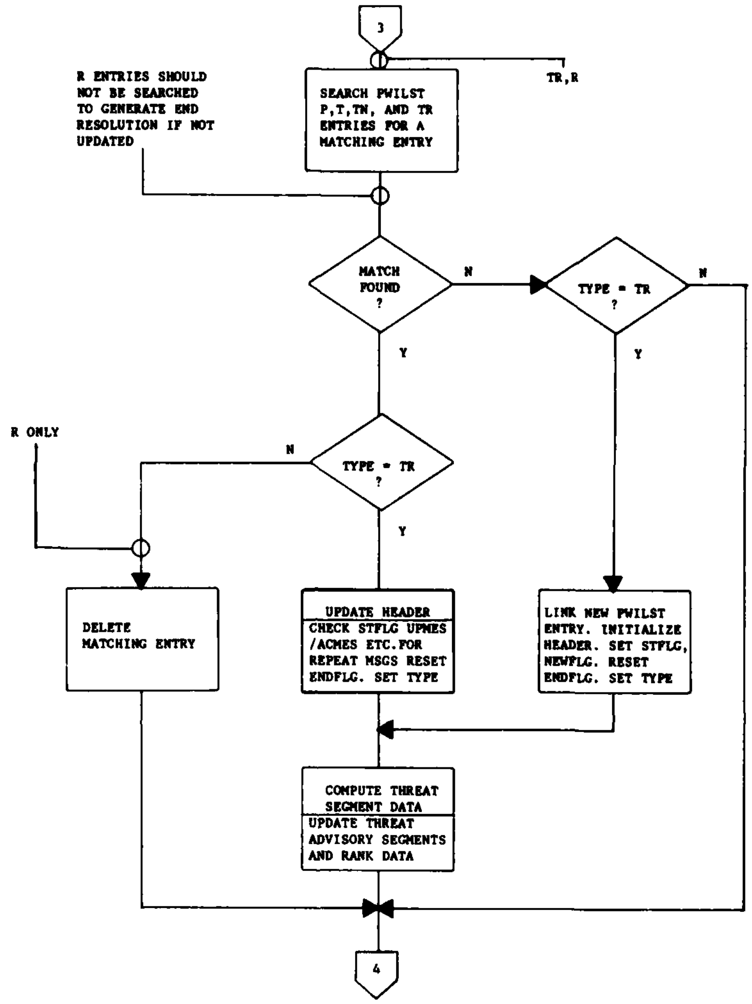


FIGURE 8-8
DATA LINK MESSAGE PRE-PROCESSING TASK (Page 3 of 4)

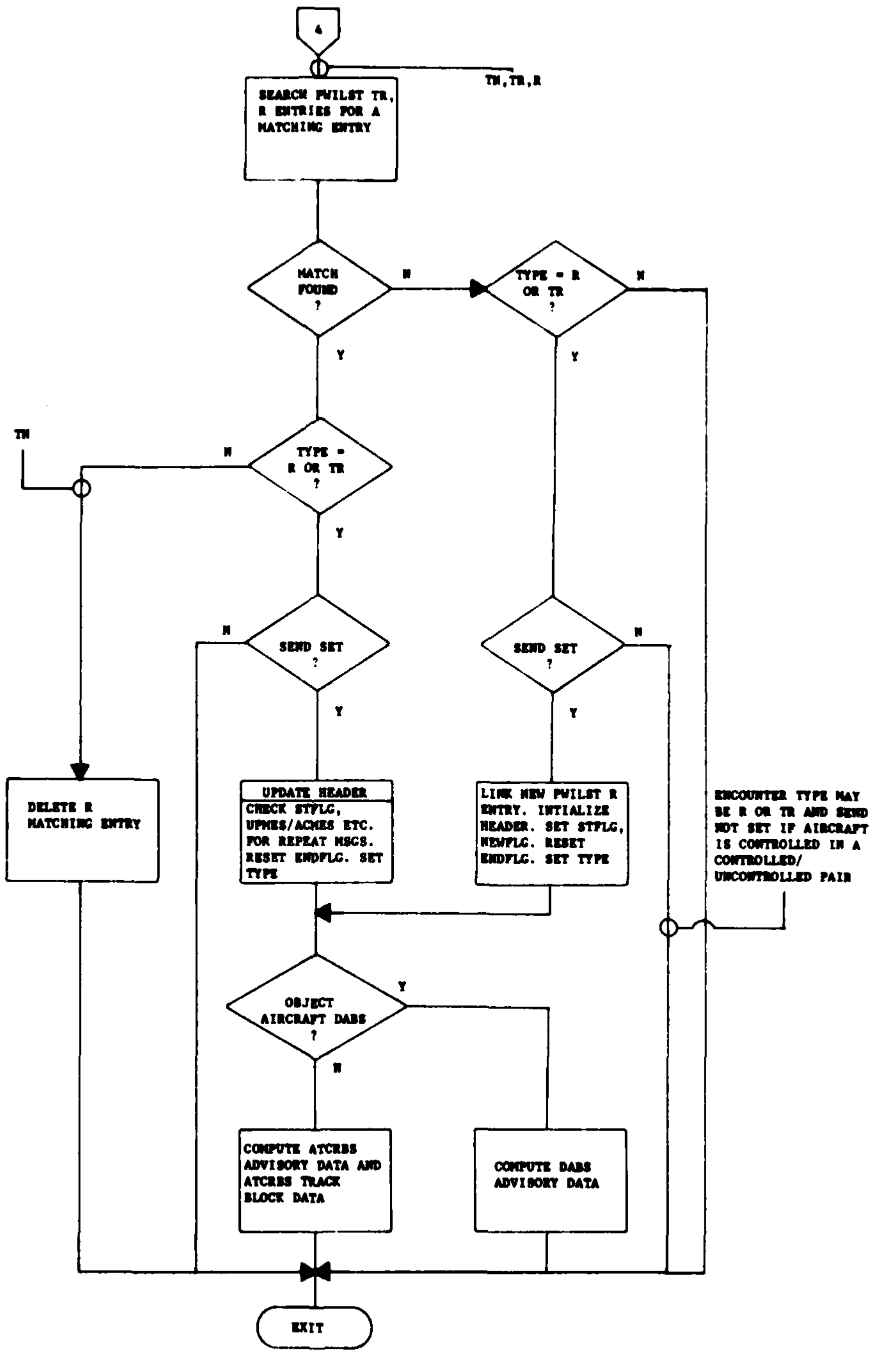


FIGURE 8-8
DATA LINK MESSAGE PRE-PROCESSING TASK (Page 4 of 4)

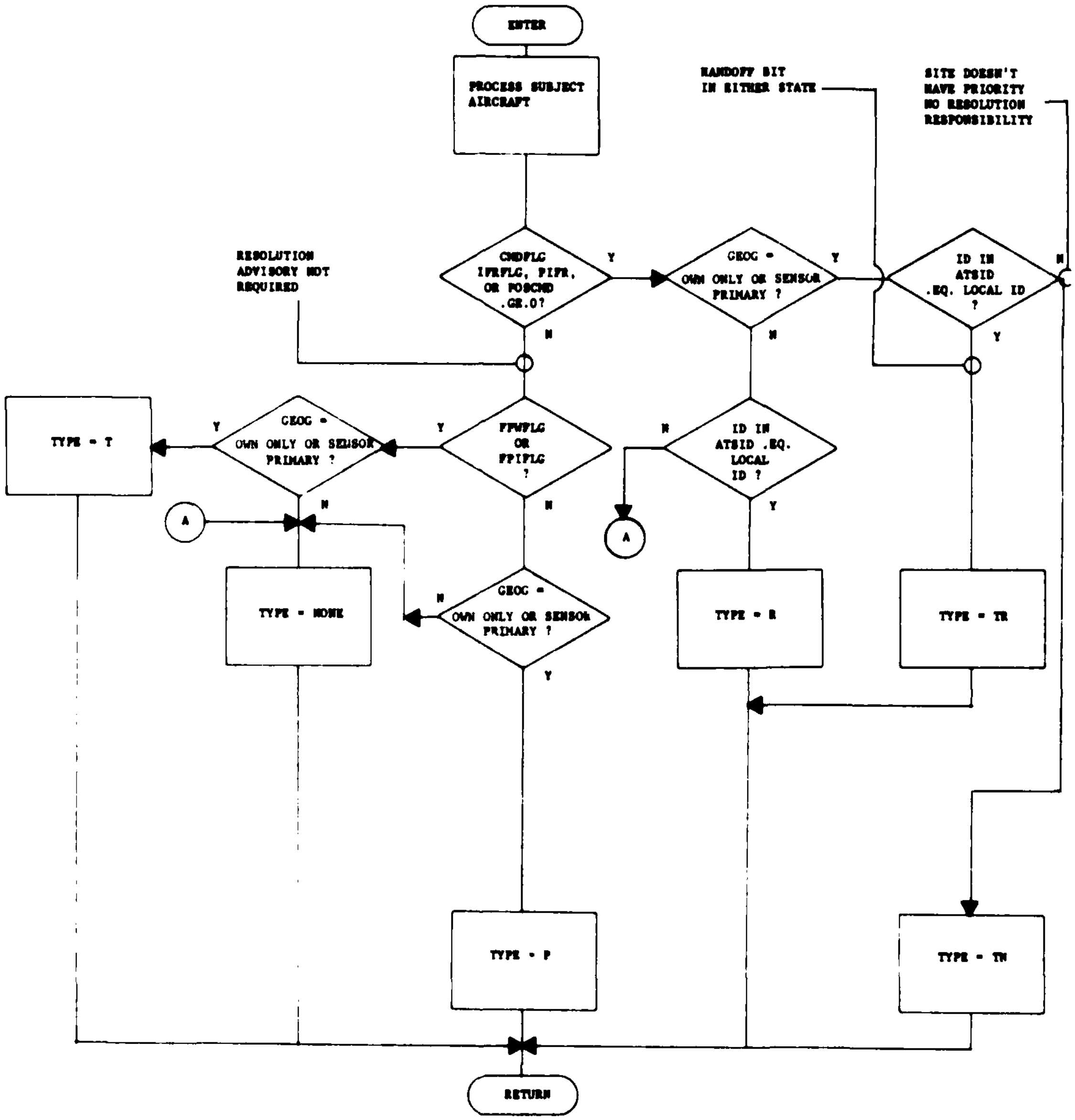


FIGURE 8-9
DETERMINE ENCOUNTER TYPE ROUTINE

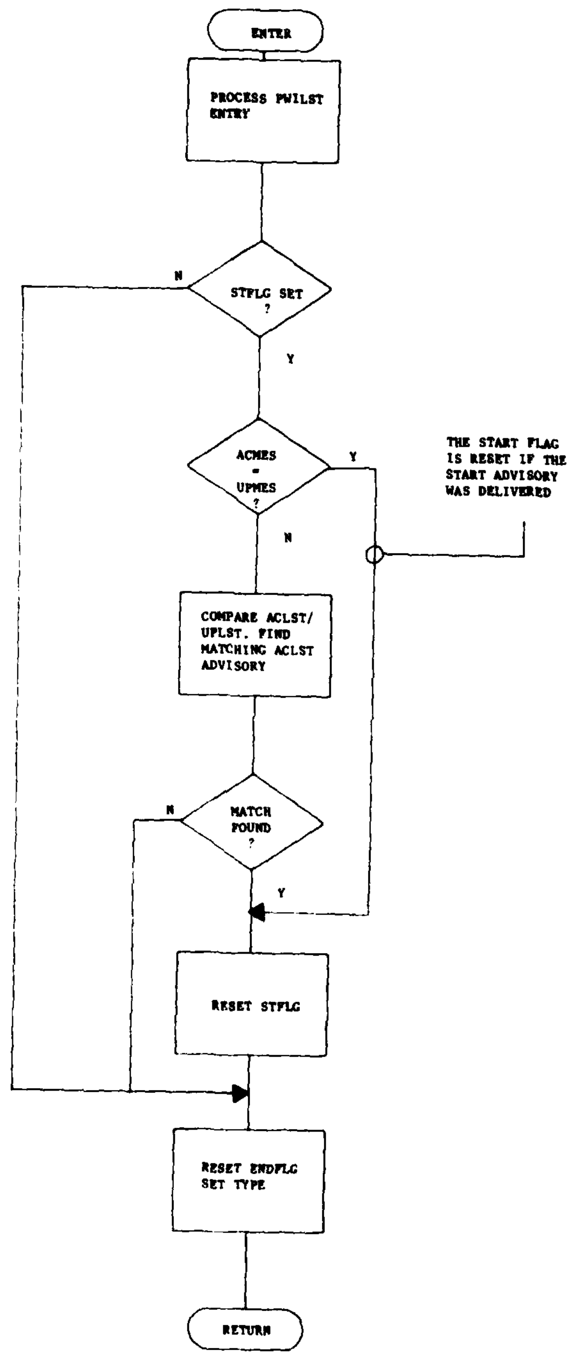


FIGURE 8-10
UPDATE HEADER ROUTINE

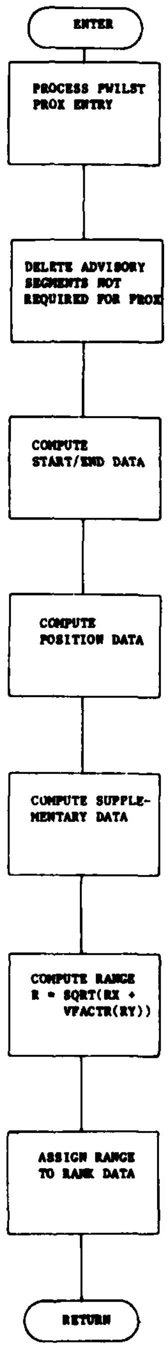


FIGURE 8-11
COMPUTE PROX SEGMENT DATA ROUTINE

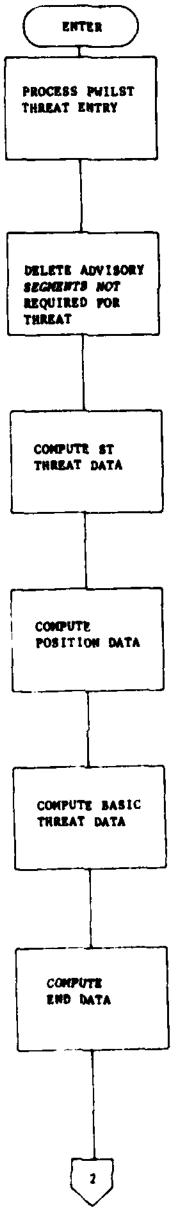


FIGURE 8-12
COMPUTE THREAT SEGMENT DATA ROUTINE (Page 1 of 2)

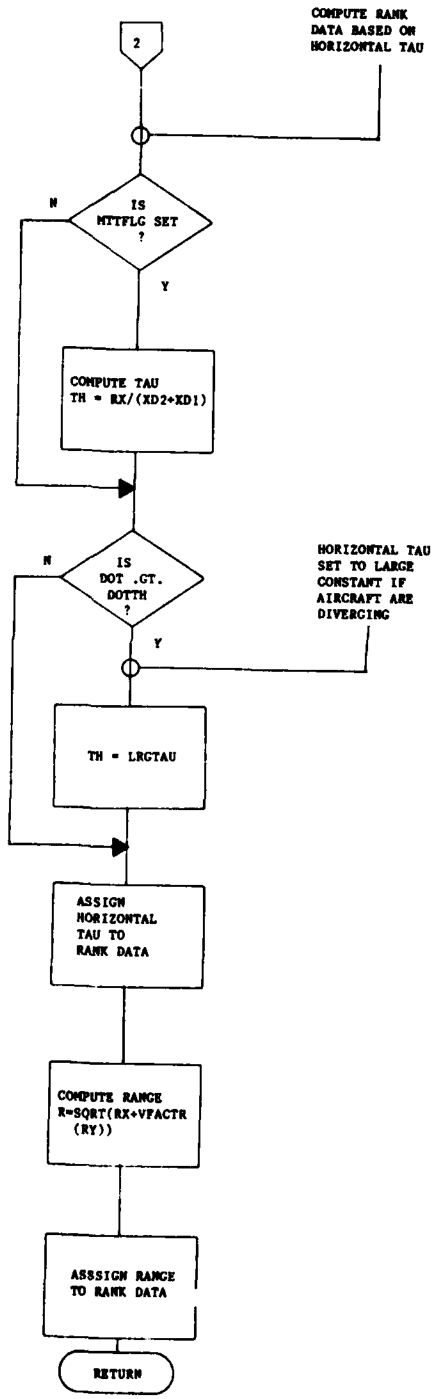


FIGURE 8-12
COMPUTE THREAT SEGMENT DATA ROUTINE (Page 2 of 2)

9. MASTER RESOLUTION TASK

The Master Resolution Task utilizes the outputs of the ATARS Detect Task to manage encounters and determine resolution advisories. Its functions are:

1. Create a pair record and create or update conflict table entries on the first scan that resolution advisories are requested for a pair of aircraft.

2. Cause resolution advisories to be issued when two requests for resolution advisories on any three consecutive scans have been generated by the detection logic or issue resolution advisories immediately when required by the MTTFLG flag setting.

3. Select the appropriate positive or negative resolution advisories for the pair using the Resolution Evaluation Routine (RER) or the Multi-aircraft Resolution Routine. Positive resolution advisories are continued for a least TSCMD seconds even if the pair drops out of resolution advisory status.

4. Monitor the change in the resolution dimension predicted miss distance and transition resolution advisories between positive and negative as required.

5. Monitor the response of aircraft to ATARS positive resolution advisories and, if necessary, issue additional resolution advisories in the event of apparent non-response as evidenced by a diminishing miss distance in the resolution dimension.

Figure 9-1 is the description of the Master Resolution Task. This task builds a multi-aircraft data structure called a conflict table along with pair records and an intermediate maneuver table for each conflict pair. The conflict table is used to manage multiple encounters in which the aircraft may be involved.

This section will discuss the overall strategy of the task, the basic two-aircraft resolution case, the special logic which is used when a multi-aircraft conflict occurs, and the handling of non-responding aircraft. Because the logic interacts extensively with the conflict table, pair records and intermediate maneuver tables, it will be necessary to discuss these data structures in detail first.

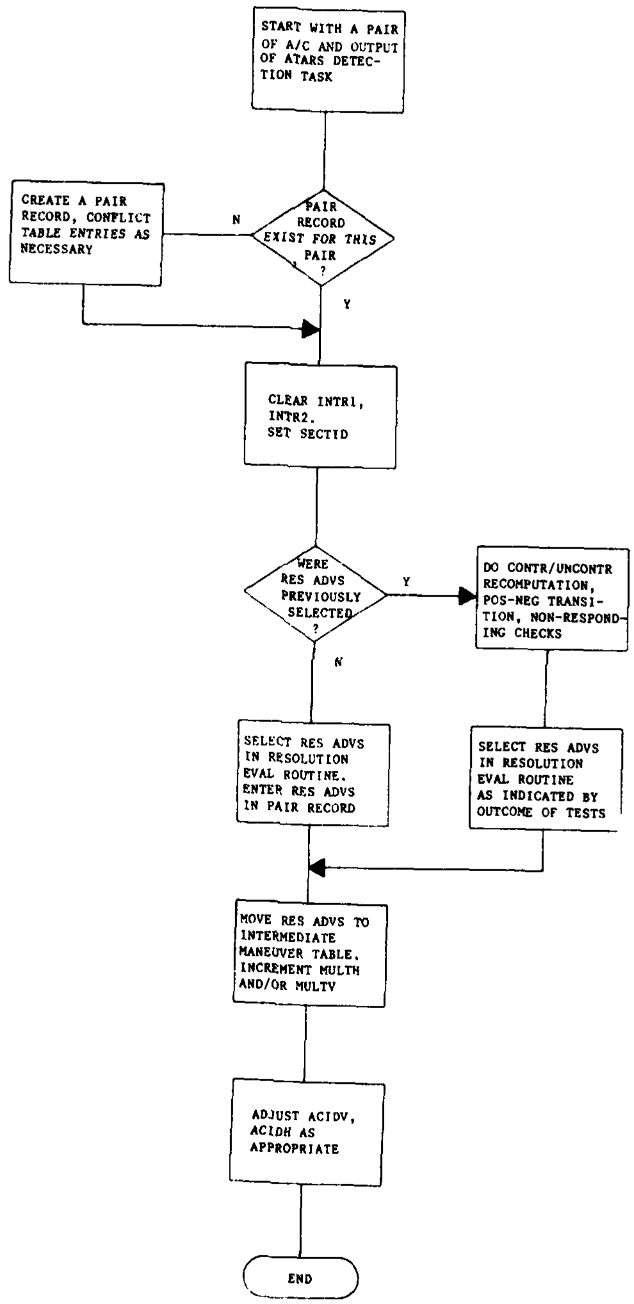


FIGURE 9-1
DESCRIPTION OF MASTER RESOLUTION TASK

9.1 Conflict Table, Pair Record and Intermediate Maneuver Table Data Structures

There are two types of data required for management of ATARS resolution:

1. inherently pairwise information, such as time at which resolution advisories were initiated or projected miss distance on previous scan, and

2. multi-aircraft information concerning the entire cluster of conflicting aircraft.

Each aircraft involved in a conflict has a pointer, CTPTR, in its system state vector pointing to the head of a conflict table. A conflict table consists of one line, or conflict table entry, for each aircraft in that conflict. The conflict table entries are linked together to permit easy insertion or deletion of aircraft (although the table could be conceptually regarded as a simple array of conflict table entries). The Conflict Table Head (Table 9-1) consists of the count of the number of aircraft in the cluster, pointers to the table head of the next and previous conflict tables in the linked list of conflict tables, a flag that indicates whether any aircraft in this conflict table is in an ATARS seam, a pointer to the list of the pair records, and a pointer to the first of the conflict table entries. The fields in each Conflict Table Entry (Table 9-2) are used to record information about the aircraft in relation to the conflict cluster, and to record the effective resolution advisories (VMAN and HMAN) for each aircraft.

The Intermediate Maneuver Table Entry (Table 9-3) contains the resolution advisory from a pair record, a pointer to that pair record, and a pointer to the next intermediate maneuver table entry for the same aircraft in the same resolution dimension. The effective resolution advisory in each dimension in the conflict table points to the intermediate maneuver table by way of ACIDH or ACIDV. All horizontal or all vertical resolution advisories for an aircraft are linked together in the intermediate maneuver table. However, the horizontal resolution advisories are not linked to the vertical resolution advisories. The use of the intermediate maneuver table simplifies identifying all the pair records and resolution advisories from those pair records in either the horizontal or vertical dimension. Also, the effective resolution advisory for the conflict table entry may easily be determined by looking at the intermediate maneuver table since only the resolution advisories for one aircraft in one dimension are linked together and pointed to by ACIDH or ACIDV.

TABLE 9-1

LOGICAL CONFLICT TABLE HEAD

FIELD		CONTENT
NAC	-	Number of aircraft currently in this conflict table.
NEXTCT	-	Pointer to the next conflict table in the linked list of conflict tables.
PREVCT	-	Pointer to the previous conflict table in the linked list of conflict tables.
SEAM	-	A flag that marks this as a seam conflict table.
PLIST	-	Pointer to first pair record for aircraft in this conflict table.
FCTE	-	Pointer to first conflict table entry in this conflict table.

TABLE 9-2

LOGICAL CONFLICT TABLE ENTRY

FIELD		CONTENT
ACID	-	This field is the identity of the aircraft in conflict, i.e., a pointer to the state vector of the aircraft.
HMAN	-	Effective horizontal resolution advisory being sent to the aircraft.
ACIDH	-	Pointer to an entry in the aircraft intermediate maneuver table that contains a pointer to the pair record causing the resolution advisory and the resolution advisory from the pair record.
MULTH	-	Count of the number of pair records causing a horizontal resolution advisory to this aircraft.
VMAN	-	Effective vertical resolution advisory being sent to the aircraft.
ACIDV	-	Pointer to an entry in the aircraft intermediate maneuver table that contains a pointer to the pair record causing the resolution advisory and the resolution advisory from the pair record.
MULTV	-	Count of the number of pair records causing a vertical resolution advisory to this aircraft.
NCON	-	Number of conflict pairs in which this aircraft is involved. Used to determine when the conflict table entry may be deleted.
REMFLG	-	Flag that indicates that this aircraft is outside the ATARS mask of the local site.
NXTCTE	-	Pointer to next conflict table entry in this conflict table.

TABLE 9-3

INTERMEDIATE MANEUVER TABLE ENTRY

FIELD		CONTENT
PRPTR	-	Pointer to the pair record that is causing this resolution advisory.
RESADV	-	The resolution advisory from the pair record. This will be a horizontal resolution advisory if ACIDH points to this entry or a vertical resolution advisory if ACIDV points to this entry.
NXTIM	-	Pointer to the next entry in the IM table that is also causing a resolution advisory to the same aircraft in the same dimension. All horizontal resolution advisories are linked together and all vertical resolution advisories are linked together. However horizontal resolution advisories are not linked to vertical resolution advisories. Null if no other conflict pairs are causing a resolution advisory in the same dimension.

For every aircraft pair declared in conflict, a pair record is created and linked into the list of pair records for this conflict table. The Pair Record (Table 9-4) contains statistics on the particular encounter underway, the selected resolution advisories for the pair, pointers to the conflict table entries of the aircraft involved, the identification of the ATARS function controlling the resolution of that pairwise conflict or an indication of BCAS control.

The interplay of the conflict table, intermediate maneuver table and pair records (as discussed in the following sections) permits:

1. The selection of resolution advisories based on the status of the entire conflict cluster under the multi-aircraft rules.

2. Management of possible modifications of resolution advisories due to negative-positive and positive-negative transitions, or non-responding logic. The basic data structures used by the algorithms and entries for a sample three-aircraft conflict are shown in Figure 9-2.

9.2 Overview

Figure 9-1 is the descriptive flow chart of the Master Resolution Task. The basic strategy of the task is to select resolution advisories for each conflict pair based on the status of all aircraft in a conflict cluster (as given in the conflict table). These advisories are recorded in the pair record and are moved into the intermediate maneuver table before the effective resolution advisory is placed in each aircraft's conflict table entry. Resolution advisories may also transition from negative to positive or positive to negative and may be adjusted by the non-responding logic.

The resolution advisories in the pair record may be thought of as representing the desired resolution advisories for this pair. The desired resolution advisories are moved into the intermediate maneuver table and the highest priority resolution advisory becomes the effective resolution advisory in the conflict table entry. As pairs go in and out of conflict, various pairs in a multi-aircraft situation will have their resolution advisories moved into the table. The conflict table entry indicates if more than one conflict pair is contributing to a resolution advisory.

The detailed logic is described in Figures 9-3 and 9-4 and discussion of logic details is given in Section 9.7.

TABLE 9-4

LOGICAL CONFLICT PAIR RECORD

FIELD		CONTENT
PAC1	-	Identity of one aircraft of the pair. For programming purposes this is a pointer to the conflict table entry for the aircraft.
PAC2	-	Identity of second aircraft of the pair. For programming purposes this is a pointer to the conflict table entry for the aircraft.
PMD	-	The square of the projected horizontal miss distance for the pair as recorded on each cycle.
PVMD	-	The projected vertical miss distance for the pair as recorded on each cycle.
TSTART	-	The time at which the present resolution advisories in the pair record were selected. The precision of this field is sufficient to determine the sequence of selecting resolution advisories given to an aircraft for more than one conflict pair in the same ATARS sector.
POSCMD	-	A control variable for managing the 2-out-of-3 conflict detection logic before giving resolution advisories and for identifying the advisories as to positive, negative or doubles.
PHMAN1, PHMAN2, PVMAN1, PVMAN2	-	The selected horizontal, vertical resolution advisories for the aircraft in the pair. Both dimensions will not necessarily be used simultaneously.
TVSL1, TVSL2	-	The time that Vertical Speed Limit (VSL) advisories were selected for each aircraft.
PIFR	-	Flag to indicate any controlled aircraft in this pair is to receive an ATARS resolution advisory.
SEND1, SEND2	-	Flag indicating that the resolution advisory in the pair record entry should be uplinked for this aircraft. SEND is set by master resolution when a resolution advisory is computed for the aircraft.

TABLE 9-4

LOGICAL CONFLICT PAIR RECORD
(Continued)

FIELD		CONTENT
ATSID	-	Identification of the ATARS processor which is controlling the resolution of this pairwise conflict. One bit of the ATSID indicates the hand-off status of ATARS control.
SECTID	-	The ATARS sector in which this conflict pair was detected.
TRKID1, TRKID2	-	The track number sent to aircraft one (two) due to the proximity advisory caused by aircraft two (one).
BIC1, BIC2	-	Counter that indicates BCAS control of this aircraft when its value is greater than zero. ATARS is in control of the pair when the value of both variables is zero.
PWISF	-	Flag to indicate that coarse screen and detection processing has already been done for this pair this scan.
INTR1	-	Pointer to the head of the list of potential domino conflict aircraft for aircraft PAC1.
INDX1	-	Value indicates which pointer in the Potential Domino Conflict List Entry to use when searching for potential domino conflict aircraft for aircraft PAC1. Value is one or two.
CMDFL1	-	Each bit of this field represents a resolution advisory. If the bit is set, then the respective resolution advisory was accounted for when determining the search limits used by the Domino Coarse Screen Routine in the selection of the present list of potential domino conflict aircraft.
INTR2	-	Pointer to the head of the list of potential domino conflict aircraft for aircraft PAC2.
INDX2	-	Value indicates which pointer in the Potential Domino Conflict List Entry to use when searching for potential domino conflict aircraft for aircraft PAC2. Value is one or two.

TABLE 9-4

LOGICAL CONFLICT PAIR RECORD
(Concluded)

FIELD		CONTENT
CMDFL2	-	Each bit of this variable represents a resolution advisory. If the bit is set, then the respective resolution advisory was accounted for when determining the search limits used by the Domino Coarse Screen Routine in the selection of the present list of potential domino conflict aircraft.
NXTPR	-	Pointer to next pair record of this conflict table.

AIRCRAFT STATE VECTORS

CTPTR	CT1
CTE	CTE1
(A/C 1)	

CTPTR	CT1
CTE	CTE2
(A/C 2)	

CTPTR	CT1
CTE	CTE3
(A/C 3)	

PAIR RECORDS

PAC1	CTE1	CTE2
PAC2	CTE3	CTE3
PMD	MD2	MD2
PVMD	ALT	ALT
TSTART	TEN	TEN
POSCMD	1	1
PHMAN1	L	
PHMAN2	R	
PVMAN1		C
PVMAN2		D
TVSL1		
TVSL2		
PIFR	0	0
SEND1	1	1
SEND2	1	1
ATSID		
SECTID		
TRKID1		
TRKID2		
BIC1	0	0
BIC2	0	0
PWISF	1	1
INTR1		
INDX2	1	1
CMDFL1		
INTR2		
INDX2	2	2
CMDFL2		
NXTPR	PR2	NULL

INTERMEDIATE MANEUVER TABLE

PRPTR	RESADV	NXTIM
PR1	L	NULL
PR1	R	NULL
PR2	C	NULL
PR2	D	NULL

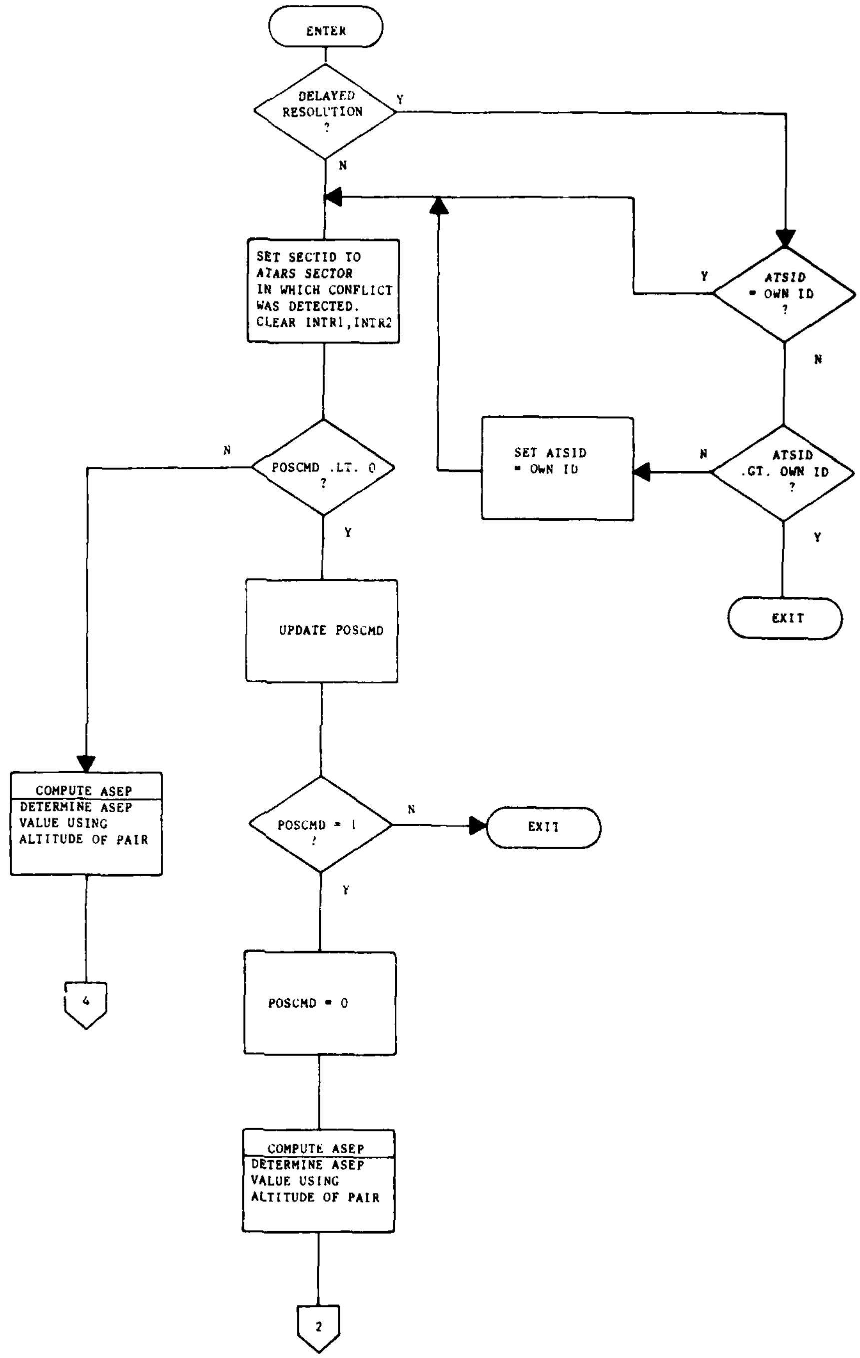
CONFLICT TABLE HEAD

NAC	3
NEXTCT	NULL
PREVCT	NULL
SEAM	0
PLIST	PR1
FCTE	CTE1

CONFLICT TABLE ENTRIES

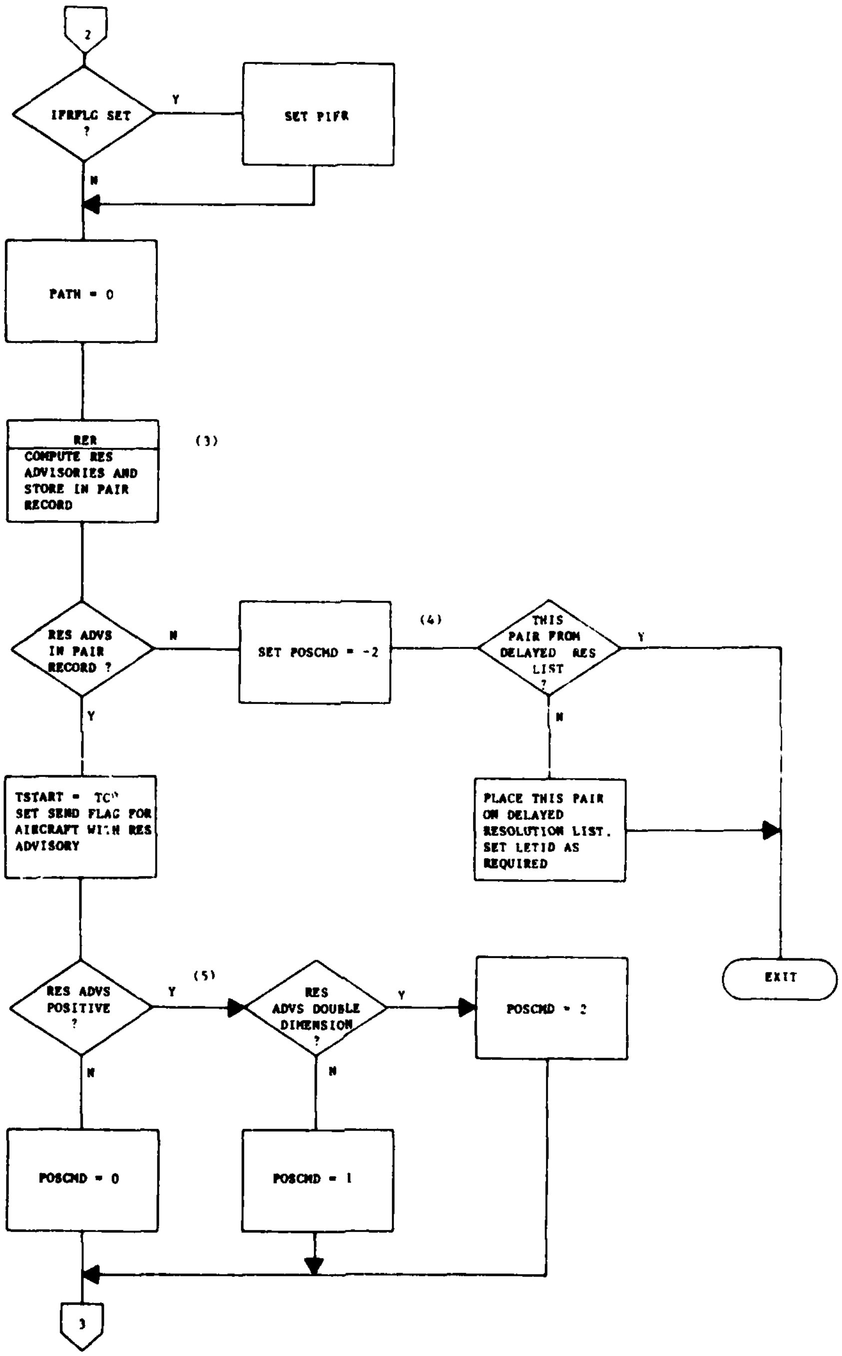
ACID	HMAN	ACIDH	MULTH	VMAN	ACIDV	MULTV	NCON	REMFLG	NXTCTE
A/C 1	L	IM1	1				1	0	CTE2
A/C 2				C	IM3	1	1	0	CTE3
A/C 3	R	IM2	1	D	IM4	1	2	0	NULL

FIGURE 9-2
DATA STRUCTURES USED BY MASTER RESOLUTION



* NUMBERS IN PARENTHESES REFER TO NOTES IN TABLE 9-7.

FIGURE 9-3
MASTER RESOLUTION TASK (PAGE 1 OF 6)



* TC IS EQUAL TO THE CURRENT SYSTEM CLOCK TIME

FIGURE 9-3
MASTER RESOLUTION TASK (Page 2 of 8)

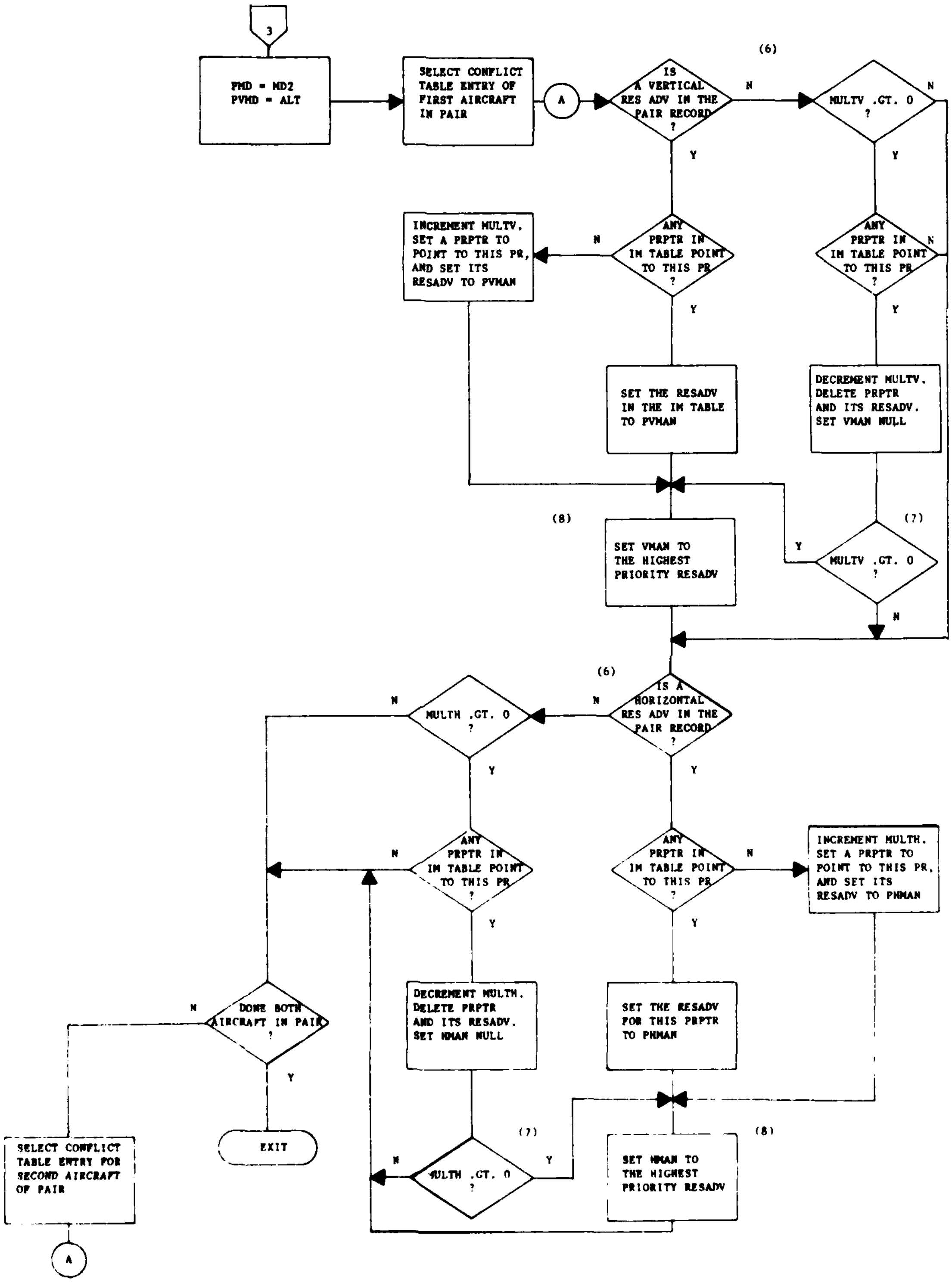


FIGURE 9-3
MASTER RESOLUTION TASK (Page 3 of 8)

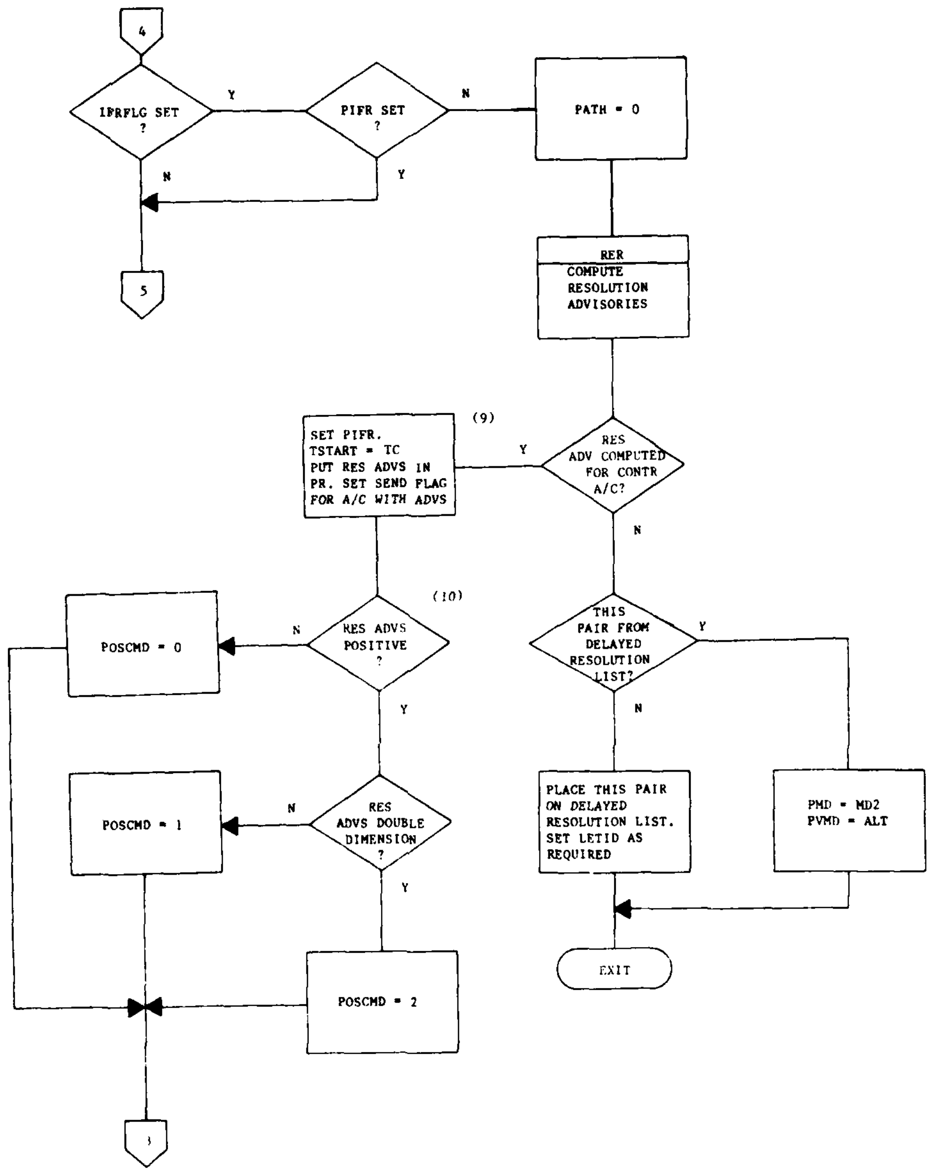


FIGURE 9-3
MASTER RESOLUTION TASK (Page 4 of 6)

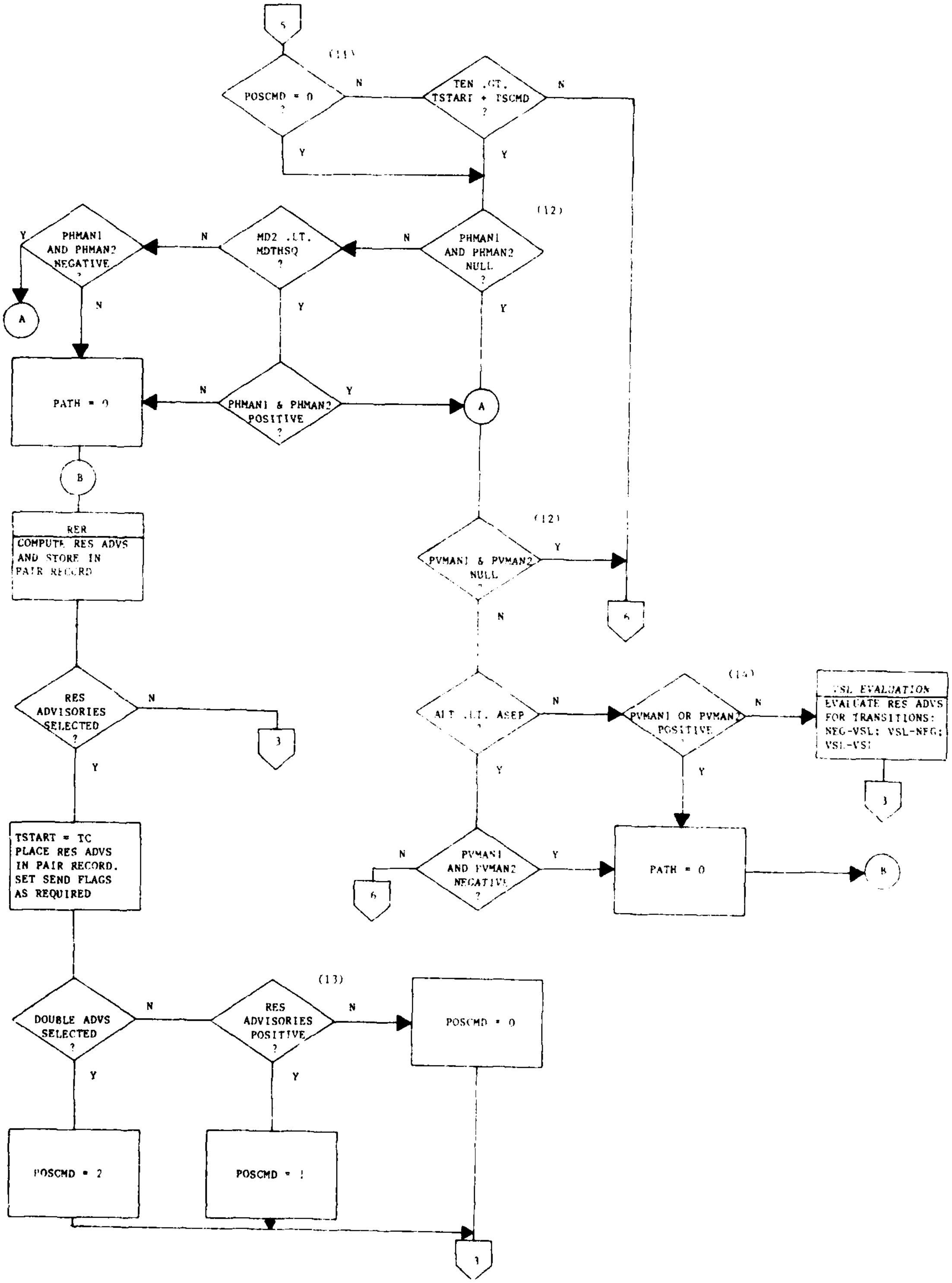


FIGURE 9-3
MASTER RESOLUTION TASK (Page 5 of 6)

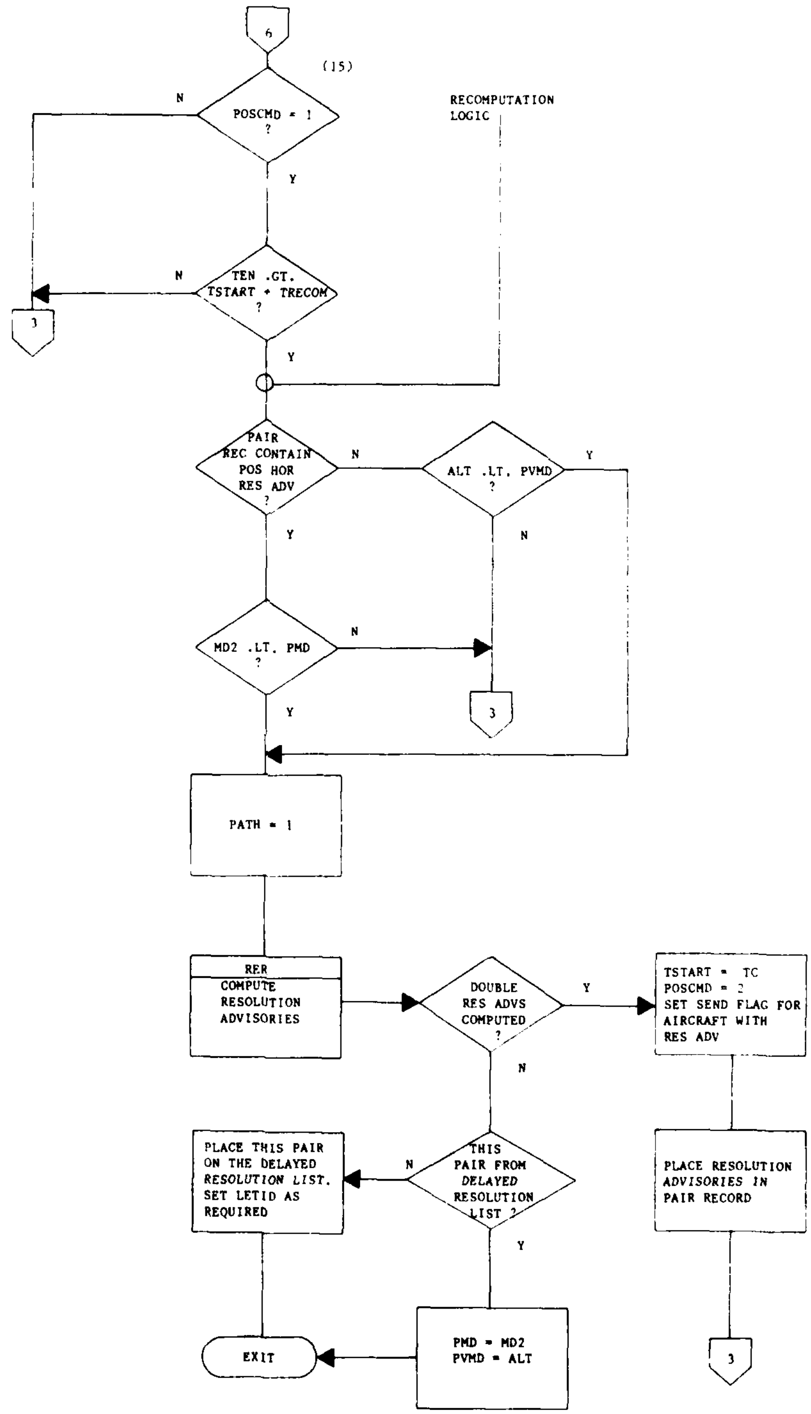


FIGURE 9-3
MASTER RESOLUTION TASK (Page 6 of 6)

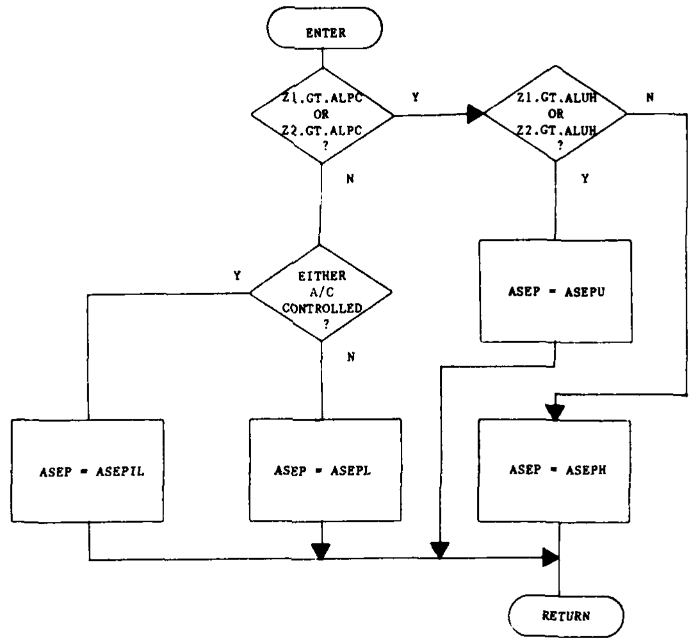


FIGURE 9-4
ASEP COMPUTATION ROUTINE

9.3 Resolution Initiation

Because ATARS decisions are based on tracked information which is subject to random fluctuations from scan to scan, it is desirable to incorporate logic to reduce false alarms when dealing with resolution advisories. Incorporating a rule which requires the conditions for issuing resolution advisories to be satisfied on two consecutive scans normally could prevent unnecessary resolution advisories because of errors on a single scan. But this rule can also lead to late alarms. If on one scan the calculations require resolution advisories, but on the second scan they do not (because of random errors) when they should, then it would require two additional scans to fully declare the conflict, and a late detection would occur. To alleviate this problem, a rule can be implemented which will issue resolution advisories if the calculations require resolution advisories on any two of three consecutive scans.

The exact way in which this is implemented is through the use of a state transition table using negative values for states of the variable, POSCMD. When a request for resolution advisories is generated for a given pair, a pair record is created and POSCMD is set to -3. POSCMD is then updated according to the transition logic in Table 9-5. POSCMD is updated on each scan that master resolution is called, until POSCMD reaches a value of +1. If POSCMD reaches a value of +1, a commitment to issue resolution advisories has been made. The MTTFLG indicates an immediate need for resolution advisories. If MTTFLG is set, then resolution advisories are calculated immediately.

The Seam Pair Task checks the CMDFLG and MTTFLG settings. When neither is set, Conflict Pair Removal Task handles the updating of POSCMD. If POSCMD reaches a state of 0 (zero), the pair is declared to be not in conflict and the pair record is deleted. The conflict table entries will be deleted if the aircraft are in no other conflict.

Resolution advisories are monitored to determine if a negative to positive or positive to negative transition is required. If it is, the new resolution advisories are reselected and entered in the pair record. When a negative transitions to a positive, the TSTART field is reset to force the positive resolution advisory to continue for at least TSCMD seconds. If positive resolution advisories have been issued in both planes in the pair record for the given pair and the resolution advisories in one plane transition to negatives, the resolution advisories in the other plane are deleted.

TABLE 9-5

POSCMD TRANSITION TABLE

PREVIOUS POSCMD	NEW VALUE OF POSCMD BASED ON VALUE OF FLAGS FOR CURRENT SCAN		
	MTTFLG		
	Set	Not Set	
		CMDFLG	
		Set	Not Set
-3	+1	-2	N/A
-2	+1	+1	-1
-1	+1	+1	0

9.4 Two Aircraft Resolution

The following logic is used to resolve all conflict pairs. If a conflict is part of a multi-aircraft situation, there may be resolution advisories in the conflict table that restrict the choice of resolution advisories so severely that the special Multi-aircraft Resolution Routine must be called. However, this is not always true. A conflict pair may be part of a larger multi-aircraft conflict, and each conflict pair may still be resolved by the two-aircraft resolution logic.

Note in the flow chart, Figure 9-3, that the resolution advisory direction for horizontal or vertical resolution advisories is not recomputed each scan except in an explicit resolution advisory change event (Sections 9.6.2 and 9.6.3). However, selection of resolution advisories is tested each scan to determine if a positive-negative or negative-positive transition should occur (Section 9.6.1).

From the standpoint of the algorithm and its data structures, the two-aircraft encounter is considered as simply a special case of an arbitrary N-aircraft encounter: i.e., the same conflict table entries, intermediate maneuver table entries and pair records are constructed. This facilitates programming and provides a uniform approach which permits subsequent aircraft to be easily merged into the two-aircraft conflict table.

The determination of resolution advisories for the unconstrained two-aircraft case is accomplished by the Resolution Evalution Routine (Section 10).

9.5 Multi-aircraft Resolution Routine

The multi-aircraft resolution logic uses the vertical or horizontal dimension to resolve simultaneous conflicts between several aircraft. The conflict table is used to plan the resolution advisories and to prevent incompatible resolution advisories from being issued to an aircraft.

Conflicts are normally resolved according to the standard two-aircraft rules of the previous section. However, in the case where one or both aircraft in a pair are interacting with other aircraft, the conflict table must be examined to see whether the desired horizontal or vertical resolution advisories can be used. If none of the potential resolution advisories can be used (Deliverable and Dimension Available Features are not both favored for any resolution advisory), then the Multi-aircraft Resolution Routine is called.

As a rule, if RER does not compute advisories because both aircraft are already receiving advisories or the only available advisories do not produce at least a minimum acceptable separation, then multi-aircraft resolution logic will also not be able to compute resolution advisories. However, if either aircraft is free in either dimension, then multi-aircraft resolution logic may be able to compute resolution advisories for one or both aircraft in this conflict pair.

The Multi-aircraft Resolution Routine first determines which resolution advisories are available for each of the maneuvered aircraft. If the subject aircraft has no resolution advisory in its conflict table entry in a dimension (VMAN or HMAN is null), but is causing resolution advisories to another aircraft because of another conflict pair (MULTV or MULTH greater than zero), then the multi-aircraft resolution logic must determine which resolution advisories are compatible with the previously detected conflict. This is done by computing predicted separation values for all potential resolution advisories for the subject aircraft versus the resolution advisory already given to the previously maneuvered aircraft. If the predicted separation for any resolution advisory satisfies the conditions of the Deliverable Feature (see Table 10-8), then that resolution advisory is available. If an aircraft has a resolution advisory in its conflict table entry, then that is the only resolution advisory (or its negative) that is available in that dimension for the subject aircraft. This determination of potential resolution advisories is done for each maneuvered aircraft.

If an aircraft is free in the vertical dimension, then both a "climb" and "descend" advisory should be examined for acceptability with the previous conflict. We would normally expect only one of the two possible vertical advisories to be compatible with the resolution of a conflict. However, if both advisories are acceptable then both advisories should become candidates for resolving the current conflict, regardless of which advisory the "eight second rule" computed for this aircraft.

After determining all the potential resolution advisories available for each aircraft, a list of potential resolution advisory sets is created. The data structure of the resolution advisory sets is that shown in Table 10-2. The list of resolution advisory sets created by the Multi-aircraft Resolution Routine will be a subset of the resolution advisories shown in Table 10-1, with the exception of a possible "climb"/"climb" or

"descend"/"descend" combination. The resolution advisory sets created are those obtained by forming all possible combinations of available same dimension resolution advisories to each maneuvered aircraft in the subject pair. Double dimension resolution advisories are obtained by forming all possible combinations of all horizontal resolution advisory sets and vertical resolution advisory sets. Then the features of Table 9-6 are evaluated for each resolution advisory set. If at least one resolution advisory set has the Deliverable Feature set, then resolution advisories can be given to this pair of aircraft. Otherwise, resolution is deferred until the next scan.

Deferring resolution is achieved in one of three ways. On initial resolution advisory selection for a pair, no resolution advisories are given and POSCMD is reset to -2. On deterioration, (IFRFLG set), the PIFR flag is not set in the pair record and no resolution advisory is given to the controlled aircraft. On non-response, do nothing (resolution advisory in other dimension can not be added at this time).

If an aircraft pair having resolution deferred is from the Normal Resolution List, then we may still be able to compute resolution advisories later this same scan. This second chance at computing resolution advisories is obtained by placing this conflict pair on the Delayed Resolution List for this sector. The pair is placed on the Delayed Resolution List and the LETID field in the entry is set to reflect this. If the pair for which resolution is being deferred is from the Delayed Resolution List, then master resolution will see that the LETID flag indicates this and attempts at resolution will be done for this scan.

If a pair for which resolution is deferred is placed on the Delayed Resolution List, then some of the same values will be recomputed on the second pass through master resolution and the Resolution Evaluation Routine as were computed on the first pass. Any values that would not change between the first pass through master resolution and the second pass should be saved. This would include some of the values in the Predicted Separation (PSEP) matrix.

Multiple encounters are handled as sequential encounters between pairs even if they are detected on the same scan. For example, assume three aircraft approaching each other in the same plane plus one aircraft (A/C #4) crossing below. The progression of the conflict tables and pair records is shown in Figure 9-5.

TABLE 9-6

MULTI-AIRCRAFT RESOLUTION ADVISORY EVALUATION CRITERIA

DELIVERABLE - If this is the first scan advisories are being given, then favor this advisory if the predicted separation of this advisory is greater than or equal to the predicted separation for the pair if no resolution advisories were given.

NEITHER DOMINO - Favor resolution advisories if neither aircraft is predicted to be in another conflict because of these resolution advisories.

ONE DOMINO - Favor resolution advisories if only one aircraft is predicted to be in another conflict because of this resolution advisory.

PSEP SEP1 - Favor resolution advisories where predicted 3-D separation is greater than SEP1. (Vertical weighted).

FAR FROM RADAR - Favor single vertical resolution advisory if either of the aircraft is further than RDISTR from the radar (i.e., SLREPS .GT. RDISTR).

NEGATIVE SUFFICES - Favor if this resolution advisory satisfies the criteria for negative resolution advisories.

NEGATIVE DOES NOT REVERSE MANEUVER - Favor if resolution advisory is negative, the pilot is maneuvering and the negative resolution advisory will not force him to stop that maneuver. Turn sensing and vertical rate sensing are used to detect a maneuver.

BIGGEST PSEP FOR NEGATIVE - Favor the resolution advisory (or resolution advisories) giving the biggest predicted separation which has NEGATIVE set.

FAST UNCMDED/SLOW CMDED - Favor double resolution advisories for a CMDED-UNCMDED encounter if the speed ratio of the UNCMDED to the CMDED is at least VRATIO, the UNCMDED is converging with a vertical rate in excess of ZDTH, and the track crossing angle is between TXTH1 and TXTH2.

UNCMDED WITH LARGE VERTICAL RATE - Favor horizontal and double resolution advisories if the UNCMDED is converging in altitude, with a vertical rate in excess of ZDTH.

TABLE 9-6

MULTI-AIRCRAFT RESOLUTION ADVISORY EVALUATION CRITERIA
(Continued)

NO LEVEL OFF TIME FOR VERTICALS - Favor horizontal and double resolution advisories if the aircraft are between TV1 and TV2 seconds from vertical crossing.

DETERIORATION - Favor double resolution advisories if the pair has satisfied the deterioration logic criteria (PATH = 1).

AIRCRAFT ON FINAL APPROACH - Favor single horizontal advisories for an aircraft in the final approach zone (FAZ set) with a ground speed of less than VFAST.

PATH DEPENDENT - Favor single resolution advisories for initial resolution advisory selection and transition (PATH = 0).

PSEP SEP2 - Favor resolution advisories where predicted 3-D separation is greater than SEP2 (vertical weighted).

COMPATIBLE WITH TURN - Favor resolution advisory where horizontal part of resolution advisory is not the opposite of a turn sensed by the tracker.

BIG VERTICAL MISS DISTANCE - Favor vertical and double resolution advisories if the existing vertical miss distance is at least ASEPV.

BIG HORIZONTAL MISS DISTANCE - Favor horizontal and double resolution advisories if the square of the projected horizontal miss distance is at least MDHSQ.

SPEED CHECK - Favor vertical and double resolution advisories if either maneuvered aircraft has a speed greater than VFAST. Favor horizontal and double resolution advisories if all maneuvered aircraft (one or both aircraft) have speeds below VSLOW.

REINFORCES PRIOR RESOLUTION ADVISORIES - Favor resolution advisory that has the same sense as the resolution advisory given on the previous scan. A double resolution advisory given after a single resolution advisory is compatible if it includes that single resolution advisory (see Table 10-9).

TABLE 9-6

MULTI-AIRCRAFT RESOLUTION ADVISORY EVALUATION CRITERIA
(Concluded)

REINFORCES TURN - Favor resolution advisory when horizontal part of the resolution advisory reinforces a turn sensed by the tracker.

BIGGEST PSEP - For all resolution advisories (single horizontal, single vertical, double) favor the resolution advisory with the largest predicted 3-D separation.

AIRCRAFT STATE VECTORS

CTPTR	CT1
CTE	CTE1
(A/C 1)	

CTPTR	CT1
CTE	CTE2
(A/C 2)	

CTPTR	NULL
CTE	NULL
(A/C 3)	

INTERMEDIATE MANEUVER TABLE

PRPTR	RESADV	NXTIM
PR1	L	NULL
PR1	NULL	NULL

PAIR RECORDS

PAC1	CTE1
PAC2	CTE2
PMD	MD2
PVMD	ALT
TSTART	TEN
POSCMD	1
PHMAN1	L
PHMAN2	NULL
PVMAN1	
PVMAN2	
TVSL1	
TVSL2	
PIFR	0
SEND1	1
SEND2	0
ATSID	
SECTID	
TRKID1	
TRKID2	
BIC1	0
BIC2	0
PWISF	1
INTR1	
INDX1	1
CMDFL1	
INTR2	
INDX2	2
CMDFL2	
NXTPR	NULL

CONFLICT TABLE HEAD

NAC	2
NEXTCT	NULL
PREVCT	NULL
SEAM	0
PLIST	PR1
FCTE	CTE1

CONFLICT TABLE ENTRIES

ACID	HMAN	ACIDH	MULTH	VMAN	ACIDV	MULTV	NCON	REMFLG	NXTCTE
A/C 1	L	IM1	1				1	0	CTE2
A/C 2	NULL	IM2	1				1	0	NULL

FIGURE 9-5
DATA STRUCTURE CONTENTS DURING MULTI-AIRCRAFT CONFLICT (Page 1 of 3)

AIRCRAFT STATE VECTORS

CTPTR	CT1
CTE	CTE1
(A/C 1)	
CTPTR	CT1
CTE	CTE2
(A/C 2)	
CTPTR	CT1
CTE	CTE3
(A/C 3)	

PAIR RECORDS

PAC1	CTE1	CTE2
PAC2	CTE2	CTE3
PMD	MD2	MD2
PVMD	ALT	ALT
TSTART	TEN	TEN
POSCMD	1	1
PHMAN1	L	
PHMAN2	NULL	
PVMAN1		D
PVMAN2		C
TVSL1		
TVSL2		
PIFR	0	1
SEND1	1	1
SEND2	0	1
ATSID		
SECTID		
TRKID1		
TRKID2		
BIC1	0	0
BIC2	0	0
PWISF	1	1
INTR1		
INDX1	1	2
CMDFL1		
INTR2		
INDX2	2	1
CMDFL2		
NXTPR	PR2	NULL

INTERMEDIATE MANEUVER TABLE

PRPTR	RESADV	NXTIM
PR1	L	NULL
PR2	NULL	NULL
PR2	D	NULL
PR2	C	NULL

CONFLICT TABLE HEAD

NAC	3
NEXTCT	NULL
PREVCT	NULL
SEAM	0
PLIST	PR1
FCTE	CTE1

CONFLICT TABLE ENTRIES

ACID	HMAN	ACIDH	MULTH	VMAN	ACIDV	MULTV	NCON	REMFLG	NXTCTE
A/C 1	L	IM1	1				1	0	CTE2
A/C 2	NULL	IM2	1	D	IM3	1	2	0	CTE3
A/C 3				C	IM4	1	1	0	NULL

FIGURE 9-5
DATA STRUCTURE CONTENTS DURING MULTI-AIRCRAFT CONFLICT (Page 2 of 3)

AIRCRAFT STATE VECTORS

CTPTR	CT1
CTE	CTE1
(A/C 1)	
CTPTR	CT1
CTE	CTE2
(A/C 2)	
CTPTR	CT1
CTE	CTE3
(A/C 3)	
CTPTR	CT1
CTE	CTE4
(A/C 4)	

INTERMEDIATE MANEUVER TABLE

PRPTR	RESADV	NXTIM
PR1	L	NULL
PR1	NULL	IM5
PR2	D	NULL
PR2	C	NULL
PR3	R	NULL
PR3	R	NULL

PAIR RECORDS

PAC1	CTE1	CTE2	CTE2
PAC2	CTE2	CTE3	CTE4
PMD	MD2	MD2	MD2
PVMD	ALT	ALT	ALT
TSTART	TEN	TEN	TEN
POSCMD	1	1	1
PHMAN1	L		R
PHMAN2	NULL		R
PVMAN1		D	
PVMAN2		C	
TVSL1			
TVSL2			
PIFR	0	1	1
SEND1	1	1	1
SEND2	0	1	1
ATSID			
SECTID			
TRKID1			
TRKID2			
BIC1	0	0	0
BIC2	0	0	0
PWISF	1	1	1
INTR1			
INDX1	1	2	2
CMDFL1			
INTR2			
INDX2	2	1	1
CMDFL2			
NXTPR	PR2	PR3	NULL

CONFLICT TABLE HEAD

NAC	4
NEXTCT	NULL
PREVCT	NULL
SEAM	0
PLIST	PR1
FCTE	CTE1

CONFLICT TABLE ENTRIES

ACID	HMAN	ACIDH	MULTH	VMAN	ACIDV	MULTV	NCON	REMFLG	NXTCTE
A/C 1	L	IM1	1				1	0	CTE2
A/C 2	R	IM2	2	D	IM3	1	3	0	CTE3
A/C 3				C	IM4	1	1	0	CTE4
A/C 4	R	IM6	1				1	0	NULL

FIGURE 9-5
DATA STRUCTURE CONTENTS DURING MULTI-AIRCRAFT CONFLICT (Page 3 of 3)

The first conflict detected is between A/C #1 and A/C #2, both at the same altitude. The resolution is achieved using a horizontal turn given to A/C #1 and a table entry is made as shown in the figure. (A/C #1 is uncontrolled, while A/C #2, #3, and #4 are controlled). On the next scan, a conflict situation is detected between A/C #2 and A/C #3. A/C #3 is directed to climb and A/C #2 is directed to descend. The next conflict occurs between A/C #2 and A/C #4 which is at a lower altitude. A horizontal maneuver is used to resolve this conflict. The resolution advisory given to A/C #2 because of A/C #4 has been checked as being compatible with the advisory to A/C #1, but it is not placed in the A/C #2 - A/C #1 pair record. At this point, it is necessary to change the value of the look-ahead time in the detection logic if provision is to be made for handling an additional conflict with the above aircraft.

As collision situations are resolved and aircraft pass clear of each other, the aircraft are dropped from the table and their pair records are deleted.

9.6 Resolution Change Logic

9.6.1 Positive/Negative Transition

Resolution advisories are monitored to determine if a negative to positive transition is required or a positive to negative transition is allowed. If it is, the new resolution advisories are reselected and entered in the pair record. When a negative transitions to a positive, the TSTART field is reset to force the positive resolution advisory to continue for at least TSCMD seconds. If positive resolution advisories have been issued in both planes in the pair record for the given pair and the resolution advisories in one plane transition to negatives, the resolution advisories in the other plane are deleted.

9.6.2 Controlled/Uncontrolled Logic

When a controlled aircraft and an uncontrolled aircraft are paired together by the coarse screen logic, normally the uncontrolled aircraft is maneuvered without maneuvering the controlled aircraft. This is accomplished by using larger tau and immediate separation thresholds to determine the need for the uncontrolled aircraft's advisory. If however, on a later scan we determine that the tau and separation values have become small enough to warrant maneuvering the controlled aircraft, RER is called to compute advisories for both aircraft.

If RER is able to compute advisories for both aircraft, then the PIFR flag is set in the pair record. If RER is not able to compute an advisory for the controlled aircraft, PIFR is not set, and resolution is deferred. Note that the advisory to the uncontrolled aircraft should not be deleted from the pair record. If this pair was from the Normal Resolution List, then set the LETID flag appropriately and place this pair on the Delayed Resolution List. This will give RER a second chance on this same scan to try to compute an advisory for the controlled aircraft.

9.6.3 Non-responding Logic

Additional logic makes a provision for recomputing and changing positive resolution advisories when either or both aircraft have not adequately responded to the resolution advisories. The horizontal (vertical) maneuver is recomputed on the first scan at least TRECOM after TSTART at which the square of the projected horizontal miss distance, MD2, (vertical miss distance, ALT) is less than the square of the projected horizontal miss distance (vertical miss distance) on the previous scan.

Note that the changed and/or additional resolution advisories continue to be sent to the non-responding aircraft since it may comply at a later time.

9.7 Detailed Logic Notes

The master resolution algorithm involves the manipulation of dynamic data structures and has several sections. A detailed description of the logic and data structures is provided below.

Certain of the flow chart blocks involve terms such as "set VMAN to the highest priority advisory" which are essential to the behavior of the system. However, including the complete logic in the flow charts would obscure the basic structure of the logic. The notes in this section are intended to annotate the flow charts and not discuss the rationale or behavior of the algorithms. Clearly, the algorithms require some type of dynamic storage allocation facility. This could be done even in a language like FORTRAN by defining a suitable set of service routines.

The use of the conflict table, intermediate maneuver table and pair record data structures should permit implementation of different multi-aircraft strategies if changes are indicated by the continuing ATARS test and analysis efforts.

Reference should be made to the following additional tables and figures while reading the explanatory notes in Table 9-7:

Illustration	Title
Figure 9-1	Description of Master Resolution Task
Figure 9-2	Data Structures Used by Master Resolution
Figure 9-3	Master Resolution Task
Table 9-1	Logical Conflict Table Head
Table 9-2	Logical Conflict Table Entry
Table 9-3	Intermediate Maneuver Table Entry
Table 9-4	Logical Conflict Pair Record
Table 9-5	POSCMD Transition Table
Table 9-8	Effective Resolution Advisory Determination

The text of the table is keyed to referenced sections of logic numbered in Figure 9-3. Also necessary to the understanding of the determination of effective resolution advisories is Table 9-8.

TABLE 9-7

LOGIC DETAILS OF MASTER RESOLUTION ALGORITHM

1. Top Level Logic (Figure 9-3, Page 1)

The master resolution algorithm is entered after the detection logic has been performed for a candidate aircraft pair generated in the coarse screening logic. Only those aircraft pairs requiring resolution advisories are processed by the master resolution logic. The top level actions are to manipulate the data structures and decide when to compute or recompute resolution advisories.

Reference	Description
1	The state vector of each aircraft contains the CTPTR pointer which points to the aircraft's conflict table. If either of the pointers for the pair are null or they point to different tables, then no pair record exists. If the pointers are identical, then we search along the linked list headed by PLIST until we find a pair record whose PAC1 and PAC2 fields point to the conflict table entries of this pair of aircraft. (Note that if the number of aircraft in the table, NAC, is 2 then the pair record pointed to immediately by PLIST must be this pair). It is advisable to save a pointer to the found pair record for use in subsequent processing steps.
2	If no pair record exists, the pair record must be created and its fields initialized. Depending on the conflict tables that may exist due to other conflict pairs, the following actions must occur. a. If both aircraft are not in a conflict table, one is created and the new pair record linked onto its pair list. b. If one aircraft is in a table and the other is not, a conflict table entry for the new aircraft is created, added to the existing table, and the new pair record linked onto the pair list.

TABLE 9-7

LOGIC DETAILS OF MASTER RESOLUTION ALGORITHM
(Continued)

c. If both aircraft in the pair are already in the same conflict table, the pair record is linked onto the conflict table's pair list.

d. If each aircraft is in a different table, the tables and pair lists are merged and the new pair record linked onto the pair list. Note that one of the existing table heads is superfluous and is deleted.

During each of these actions, the number of aircraft field, NAC, in the resulting table, must be appropriately incremented. The NCON field in each aircraft's conflict table entry is incremented to reflect the presence of the new conflict pair. The CTPTR fields in each aircraft's state vector must be appropriately adjusted.

2. Initial Resolution Advisory Select Logic (Figure 9-3, Page 2)

The initial resolution advisory select logic selects the resolution advisories for the pair of aircraft and enters them into the pair record. This page of logic is entered when a pair record exists, the CMDFLG is set, and no resolution advisories have been selected in the pair record.

Reference	Description
3	RER chooses the appropriate resolution advisories for the pair. If only one aircraft is to be maneuvered, no resolution advisory will be determined for the unmaneuvered aircraft and a null entry is placed in the pair record for that aircraft. The domino and multi-aircraft resolution logic is a subset of the RER. RER determines when to call both of these routines.
4	If resolution advisories could not be computed for the pair of aircraft due to other conflict constraints, then resolution is deferred until the next scan. This is accomplished at initial resolution advisory selection by resetting POSCMD

TABLE 9-7

LOGIC DETAILS OF MASTER RESOLUTION ALGORITHM
(Continued)

to -2. If the *CMDFLG* is set again on either of the next two scans for this pair, then master resolution will again call the RER to compute resolution advisories. If this pair was from the Normal Resolution List then attempt resolution again this scan by placing this pair on the Delayed Resolution List.

The Path variable tells the RER which advisories to favor; single dimension or double dimension. PATH=0 means to favor single dimension advisories and PATH=1 means to favor double dimension advisories. Single dimension advisories are favored on initial advisory selection, uncontrolled/controlled advisory addition, and positive to negative and negative to positive advisory transition. Double dimension advisories are favored when the situation is deteriorating as evidenced by a decreasing miss distance in the resolution dimension.

5 If horizontal resolution advisories were computed, then both advisories are either positive or negative. If vertical resolution advisories were computed, both advisories are positive or negative, unless a "descend" resolution advisory was computed for an aircraft below ATERN altitude AGL. In this case, one advisory is positive and one negative. This case should be treated as positive advisories.

<u>3. Post Resolution Advisories from Pair Record to Conflict Table (Figure 9-3, Page 3)</u>

In general, the pair record contains the resolution advisories to resolve a particular conflict pair selected in the initial resolution advisory select logic or modified in the resolution advisory change logic. Because of prior conflicts, the effective resolution advisories in the conflict table entry are not always identical with the advisories in the pair record. This section of logic moves resolution advisories from the pair record to the conflict table through the use of the intermediate maneuver table.

TABLE 9-7

LOGIC DETAILS OF MASTER RESOLUTION ALGORITHM
(Continued)

This staging of resolution advisories from the pair record to the conflict table permits:

a. resolution advisories to be changed or added due to events in this pair, and

b. proper changes in the remaining resolution advisories when pairs go in or out of conflict.

Reference	Description
6	If the resolution advisory in the pair record is null, we must distinguish between no resolution advisory and a null advisory. A null advisory may be given to a controlled aircraft while the uncontrolled aircraft is receiving a resolution advisory in this dimension. This may be done by using different codes in the pair record for no resolution advisory and for a null resolution advisory (see Table 10-3). The intermediate maneuver table contains a resolution advisory in one dimension and a pointer to the pair record causing the advisory. If there is a resolution advisory in the pair record this scan, then check the intermediate maneuver table. If this pair record is already in the intermediate maneuver table in this dimension, then simply update the advisory to the advisory in the pair record. If the pair record is not already in the intermediate maneuver table in this dimension, then add an entry for this pair record, add the resolution advisory and increment MULTH (MULTV) in the conflict table entry. If no resolution advisory appears in the pair record for an aircraft, then no entry needs to be made in the intermediate maneuver table. This is not true when a controlled aircraft has a null resolution advisory in a dimension but the uncontrolled aircraft it is paired with does have a resolution advisory in that dimension. F. that

TABLE 9-7

LOGIC DETAILS OF MASTER RESOLUTION ALGORITHM
(Continued)

	dimension only, a null resolution advisory entry is made in the intermediate maneuver table and factored into the effective resolution advisory in the conflict table entry. The MULTH or MULTV counter is incremented also.
7	A resolution advisory is being deleted for this aircraft based on this particular pair record. However, this aircraft may require another advisory based on another pair. Yet the other pair may have been processed already this scan, so that there would be a one scan delay in setting the conflict table entry advisory to the advisory from the second pair. Therefore, advisories caused by other pairs are checked for and sent to the conflict table entries at this point, regardless of whether the other pair has already been processed this scan.
8	The highest level resolution advisory should be placed in the conflict table entry. In most cases, only one pair record will be causing an advisory to an aircraft in a dimension (MULTH or MULTV =1). In this case, the advisory may be moved directly from the intermediate maneuver table to the conflict table entry. If more than one pair record is causing an advisory in one dimension, the highest level advisory is moved to the conflict table entry. The RER should not pick conflicting sense advisories, but because of seam conflicts and BCAS chosen advisories, conflicting sense resolution advisories should be accounted for. In the horizontal dimension, there are only two levels of advisories, positive and negative. In the vertical dimension there are three levels, positive, negative and VSL. Within the VSL level, there are three sublevels. The positive advisories are the highest level, while negative advisories are next and VSL's the lowest level.

TABLE 9-7

LOGIC DETAILS OF MASTER RESOLUTION ALGORITHM
(Continued)

Table 9-8 indicates the decisions to be made in choosing the highest level advisory. Even though there may be more than two advisories, the decision may be made between two advisories at a time; an advisory in the intermediate maneuver table and the effective advisory already in the conflict table entry.

<u>Resolution Advisory Change Logic (Figure 9-3, Pages 4, 5, 6)</u>

There are three ways in which resolution advisories can be modified once they are selected in the initial resolution advisory select logic:

a. a controlled aircraft requiring a resolution advisory (Page 4),

b. a positive to negative or negative to positive resolution advisory transition (Page 5),

c. a non-responding aircraft in the pair (Page 6).

The non-responding logic monitors the conflict and adds another resolution advisory if one aircraft did not respond as indicated by a diminishing horizontal or vertical miss distance.

POSCMD is a control variable used to implement this logic. Prior to the commitment to issue resolution advisories, POSCMD takes a series of negative values. These are explained in Section 9.3. The non-negative values of POSCMD and their meanings are listed below.

POSCMD = 0	Negative resolution advisories selected
POSCMD = 1	Positive resolution advisories have been computed and entered in the pair record. An additional maneuver has not yet been generated.
POSCMD = 2	A horizontal or vertical maneuver has been recomputed, and stored in the pair record because a decrease in projected horizontal or vertical miss distance has been detected.

TABLE 9-7

LOGIC DETAILS OF MASTER RESOLUTION ALGORITHM
(Continued)

4. Recomputation of Resolution Advisories when Controlled/ Uncontrolled Conflict Cannot be Resolved by Maneuvering Only the Uncontrolled (Figure 9-3, Page 4)

9	It is now necessary to give a resolution advisory to the controlled aircraft. However, it is possible that since the scan on which the uncontrolled aircraft received its resolution advisory, the controlled aircraft has acquired constraints on it due to other conflicts. If a resolution advisory can not be given to the controlled aircraft for this conflict pair, then resolution must be deferred. This is done by keeping the advisory to the uncontrolled aircraft, but not setting the PIFR flag in the pair record. Then, if the IFRFLG is set again on the next scan, again attempt to compute resolution advisories for the controlled aircraft. Instead of just deferring resolution to the next scan, if this pair was from the Normal Resolution List, then place the pair on the Delayed Resolution List and set the LETID flag in the entry appropriately.
10	Comment 5 applies here also.

5. Resolution Advisory Transition Logic (Figure 9-3, Page 5)

11	If POSCMD=0, then negative resolution advisories are in the pair record. If POSCMD is greater than 0, then positive single or double dimension advisories are in the pair record. Check for transition only if the positive advisories have been in the pair record at least TSCMD seconds.
12	If resolution advisories appear in the pair record in this dimension, check their sense (positive or negative) against the sense of advisories necessary as indicated by the projected miss distance. While the test for the Negative Suffices Feature in RER involves more than simply a miss distance check,

TABLE 9-7

LOGIC DETAILS OF MASTER RESOLUTION ALGORITHM
(Concluded)

	the miss distance check is the best single indicator of the need for positive or negative advisories.
13	Comment 5 applies here also.
14	Comment 5 explains why the vertical dimension test is an "OR" test while the horizontal dimension test is an "AND" test.

6. Non-responding Logic (Figure 9-3, Page 6)

15	Positive, single dimension resolution advisories must have been given for at least TRECOM seconds before a check for the necessity for double dimension advisories is made . If, after TRECOM seconds of positive advisories, the projected miss distance in the resolution dimension diminishes from the previous scan, then call the RER to compute two dimensional resolution advisories. If double advisories can not be computed, defer resolution by leaving POSCMD set to 1. Attempts will be made to compute double dimension advisories on any subsequent scan on which the projected miss distance decreases in the resolution dimension from the previous scan.

TABLE 9-8

EFFECTIVE RESOLUTION ADVISORY DETERMINATION

HORIZONTAL RESOLUTION ADVISORY IN INTERMEDIATE MANEUVER TABLE ENTRY

		TL	TR	DTR	DTL	NULL
HORIZONTAL	TL	1**	*	1	*	1
RESOLUTION	TR	*	2	*	2	2
ADVISORY	DTR	1	*	3	5	3
IN	DTL	*	2	5	4	4
CONFLICT	DTR/DTL	*	*	5	5	5
TABLE	NULL	1	2	3	4	6
ENTRY						

VERTICAL RESOLUTION ADVISORY IN INTERMEDIATE MANEUVER TABLE ENTRY

		CL	DES	DDES	DCL	LIMDES (7)	LIMCL (8)	LIMDES (9)	LIMCL (10)	LIMDES (11)	LIMCL (12)	NULL
	CL	1	*	1	*	1	*	1	*	1	*	1
	DES	*	2	*	2	*	2	*	2	*	2	2
VERTICAL	DDES	1	*	3	5	3	5	3	5	3	5	3
RESOLUTION	DCL	*	2	5	4	5	4	5	4	5	4	4
ADVISORY	DCL/DDES	*	*	5	5	5	5	5	5	5	5	5
IN	LIMDES(7)	1	*	3	5	7	5	9	5	11	5	7
CONFLICT	LIMCL(8)	*	2	5	4	5	8	5	10	5	12	8
TABLE	LIMDES(9)	1	*	3	5	9	5	9	5	11	5	9
ENTRY	LIMCL(10)	*	2	5	4	5	10	5	10	5	12	10
	LIMDES(11)	1	*	3	5	11	5	11	5	11	5	11
	LIMCL(12)	*	2	5	4	5	12	5	12	5	12	12
	NULL	1	2	3	4	7	8	9	10	11	12	6

---

* Non-compatible combination

** See Table 10-3 for definition of resolution advisory codes.

10. RESOLUTION EVALUATION ROUTINE

The Resolution Evaluation Routine (RER) is called by the Master Resolution Task to determine maneuvers for a pair of aircraft requiring resolution advisories. RER receives as input the aircraft state vectors, the values computed in the Detect Task, and any conflict tables, intermediate maneuver tables and pair records that exist. The module generates positive or negative horizontal or vertical resolution advisories or Vertical Speed Limit (VSL) resolution advisories for each maneuvered aircraft. The description of the Resolution Evaluation Routine is presented in Figure 10-i.

Resolution advisories are generated by evaluating all resolution advisory sets and picking the set with the highest total value of favored features. To reduce computation, only a subset of all possible resolution advisory sets is considered. This subset consists of the 25 resolution advisories shown in Table 10-1. The associated data structure is Table 10-2. Table 10-3 gives the definition of the codes used in Table 10-1.

Of the 25 resolution advisories, nine maneuver both aircraft, eight maneuver only the first and the other eight maneuver only the second. Whether both aircraft are to be maneuvered is a function of the aircraft configuration (controlled/uncontrolled, equipped/unequipped), the flags set in the Detect Task, and the zone where the conflict takes place (see Tables 10-4 and 10-5). Aircraft which are to receive a resolution advisory are maneuvered and those which are not are unmaneuvered. After the maneuvering aircraft are determined, the 25 resolution advisories in Table 10-1 are reduced to eight or nine applicable resolution advisories.

The set of resolution advisories may be implemented as a list of data structures linked together. The data structure for a resolution advisory is shown in Table 10-2. Some of the data fields describe intrinsic properties of each resolution advisory and are hardwired, while others depend on the encounter and are computed by the resolution evaluation logic. Some of the information in the resolution advisory data structure is redundant, but is included to simplify the evaluation logic.

When both aircraft are expected to respond to resolution advisories, there is only one sensible vertical resolution advisory pair. This sensible vertical resolution advisory pair can be found by projecting the aircraft ahead eight seconds and giving the aircraft on top a "climb" and the one below a "descend." For the resolution advisories that maneuver both aircraft in the

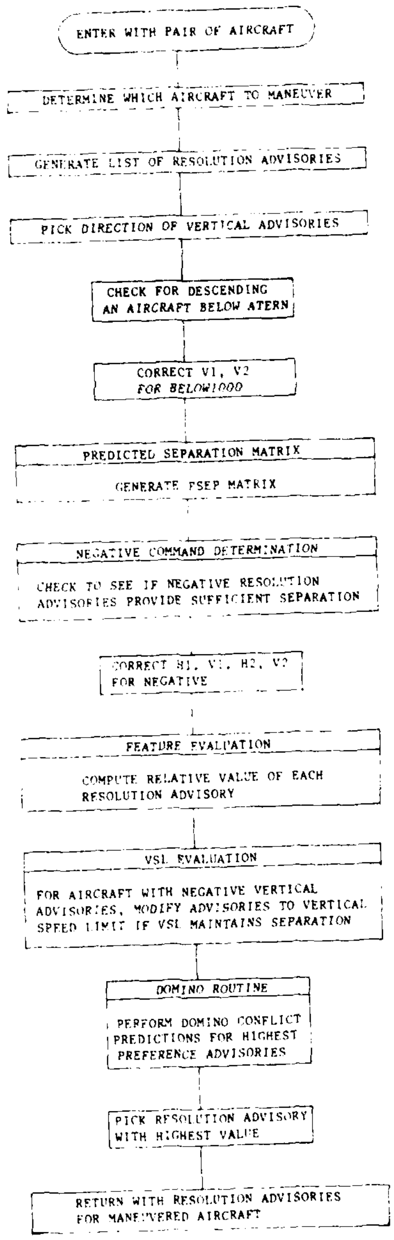


FIGURE 10-1
DESCRIPTION OF RESOLUTION EVALUATION ROUTINE

TABLE 10-1

SET OF RESOLUTION ADVISORIES TO BE EVALUATED

	B				C						Array Index		
	H1	V1	H2	V2	SINGLE	HORIZ	VERT	CMDED-CMDED[A]	CMDED-UNCMDED	UNCMDED-CMDED	INDEX1	INDEX2	INDEX3
TL/-	1	0	6	0	1	1	0	0	1	0	1	2	1
TR/-	2	0	6	0	1	1	0	0	1	0	3	2	1
C/-	0	1	0	6	1	0	1	0	1	0	2	2	3
D/-	0	2	0	6	1	0	1	0	1	0	2	2	2
TL/- C/-	1	1	6	6	0	1	1	0	1	0	1	2	3
TR/- C/-	2	1	6	6	0	1	1	0	1	0	3	2	3
TL/- D/-	1	2	6	6	0	1	1	0	1	0	1	2	2
TR/- D/-	2	2	6	6	0	1	1	0	1	0	3	2	2
TL/TL	1	0	1	0	1	1	0	1	0	0	1	1	1
TL/TL VERT	1	*	1	*	0	1	1	1	0	0	1	1	2
TL/TR	1	0	2	0	1	1	0	1	0	0	1	3	1
TL/TR VERT	1	*	2	*	0	1	1	1	0	0	1	3	2
VERT	0	*	0	*	1	0	1	1	0	0	2	2	2
TR/TL	2	0	1	0	1	1	0	1	0	0	3	1	1
TR/TL VERT	2	*	1	*	0	1	1	1	0	0	3	1	2
TR/TR	2	0	2	0	1	1	0	1	0	0	3	3	1
TR/TR VERT	2	*	2	*	0	1	1	1	0	0	3	3	2
-/TL	6	0	1	0	1	1	0	0	0	1	2	1	1
-/TR	6	0	2	0	1	1	0	0	0	1	2	3	1
-/C	0	6	0	1	1	0	1	0	0	1	2	2	3
-/D	0	6	0	2	1	0	1	0	0	1	2	2	2
-/TL -/C	6	6	1	1	0	1	1	0	0	1	2	1	3
-/TR -/C	6	6	2	1	0	1	1	0	0	1	2	3	3
-/TL -/D	6	6	1	2	0	1	1	0	0	1	2	1	2
-/TR -/D	6	6	2	2	0	1	1	0	0	1	2	3	2

* Will be replaced by the appropriate vertical resolution advisories, picked using the "eight second rule."

A CMDED - maneuvered (commanded); UNCMDED - unmaneuvered (uncommanded)

B The numerical coding scheme for the resolution advisories is given in Table 10-3.

C 1 - True, 0 - False

TABLE 10-2

RESOLUTION ADVISORY DATA STRUCTURE

FIELD		DEFINITION
H1	-	Horizontal component of resolution advisory to aircraft 1.
V1	-	Vertical component of resolution advisory to aircraft 1.
H2	-	Horizontal component of resolution advisory to aircraft 2.
V2	-	Vertical component of resolution advisory to aircraft 2.
SINGLE	-	Set if resolution advisories are only horizontal or only vertical.
HORIZ	-	Set if there is a horizontal component to this resolution advisory.
VERT	-	Set if there is a vertical component to this resolution advisory.
CMDED-CMDED	-	Set if this resolution advisory maneuvers both aircraft.
CMDED-UNCMDED	-	Set if this resolution advisory maneuvers only the first aircraft.
UNCMDED-CMDED	-	Set if this resolution advisory maneuvers only the second aircraft.
NEGATIVE	-	Set if the same sense negative of this resolution advisory will provide sufficient separation.
BELOW1000	-	Set if this resolution advisory contains a "descend" that is changed to a "don't climb."
INDEX1	-	Index into PSEP for the horizontal resolution advisory for the first aircraft.

TABLE 10-2

RESOLUTION ADVISORY DATA STRUCTURE
(Concluded)

FIELD		DEFINITION
INDEX2	-	Index into PSEP corresponding to the horizontal resolution advisory for the second aircraft.
INDEX3	-	Index into the appropriate vertical level of PSEP.
VALUE	-	Will be set to indicate the relative value of this resolution advisory.
NXTADV	-	Pointer to next resolution advisory.

TABLE 10-3

RESOLUTION ADVISORY TRANSLATION TABLE:
ATARS REPRESENTATION/CIR REPRESENTATION

RESOLUTION ADVISORY	ATARS CODE	CIR CODE D FIELD	CIR CODE VSL FIELD
No Res Adv	0	0000000000	00
Null Res Adv	6	0000000000	00
HORIZONTAL			
Turn Left (TL)	1	1000000000	00
Turn Right (TR)	2	1010000000	00
Don't Turn Right (DTR)	3	1100000000	00
Don't Turn Left (DTL)	4	1110000000	00
Don't Turn Left/ Don't Turn Right (DTL/DTR)	5	N/A	
VERTICAL			
Climb (CL)	1	0001000000	00
Descend (DES)	2	0001001000	00
Don't Descend (DDES)	3	0001100000	00
Don't Climb (DCL)	4	0001101000	00
Don't Climb/ Don't Descend (DCL/DDES)	5	N/A	
Limit Descent 2000ft/min (LIMDES)	7	0001111000	11
Limit Climb 2000ft/min (LIMCL)	8	0001110000	11
Limit Descent 1000ft/min (LIMDES)	9	0001111000	10
Limit Climb 1000ft/min (LIMCL)	10	0001110000	10
Limit Descent 500ft/min (LIMDES)	11	0001111000	00
Limit Climb 500ft/min (LIMCL)	12	0001110000	00

* For double dimension advisories the CIR code is the logical OR of the codes for the separate dimensions.

TABLE 10-4

WHICH AIRCRAFT TO MANEUVER WHEN NEITHER IS IN FINAL APPROACH ZONE

	AIRCRAFT 1			
AIRCRAFT 2	Controlled Equipped	Controlled Unequipped	Uncontrolled Equipped	Uncontrolled Unequipped
Controlled Equipped	Both	AC2	AC1*	AC2
Controlled Unequipped	AC1	Neither	AC1	Neither
Uncontrolled Equipped	AC2*	AC2	Both	AC2
Uncontrolled Unequipped	AC1	Neither	AC1	Neither

* Both aircraft will be maneuvered if PIFR is set

TABLE 10-5

WHICH AIRCRAFT TO MANEUVER WHEN AC2 IS IN FINAL APPROACH ZONE

	AIRCRAFT 1			
AIRCRAFT 2	Controlled Equipped	Controlled Unequipped	Uncontrolled Equipped	Uncontrolled Unequipped
Controlled Equipped	AC1	AC2	AC1	AC2
Controlled Unequipped	AC1	Neither	AC1	Neither
Uncontrolled Equipped	AC1	AC2	AC1	AC2
Uncontrolled Unequipped	AC1	Neither	AC1	Neither

Rule to determine which aircraft to maneuver.

If one of the aircraft is on final approach,

1. Give resolution advisories to the aircraft not on final approach if it is equipped.

2. Give resolution advisories to the aircraft on final approach if the other aircraft is unequipped.

vertical dimension, the vertical maneuvers are not hardwired, but are computed using this "eight second rule." The same is not done when one aircraft is to get a resolution advisory, because it may be desirable to maneuver one aircraft toward another to avoid a vertical chase.

One of the criteria used to evalute a resolution advisory is the separation that resolution advisory is expected to produce. The predicted separation (PSEP) is determined by using a fast time simulation to model the aircraft responding to resolution advisories. This procedure is explained in Predicted Separation Matrix (Section 10.1). This model is also used to determine whether the negative of a resolution advisory provides sufficient separation.

Reference to the negative of a resolution advisory always means the negative of the opposite direction advisory. That is, the negative of a "turn left" is not "don't turn left," but "don't turn right." The negative of "turn right" is "don't turn left." The negative of "climb" is "don't descend" and the negative of "descend" is "don't climb."

Once the list of possible resolution advisories is set up and the PSEP matrix is generated, the resolution advisories can be evaluated. The evaluation criteria include safety and predicted separation. The evaluation process is described in Feature Evaluation (Section 10.2).

RER logic selects positive resolution advisories in the horizontal or vertical dimension then modifies those resolution advisories to negative as a special case of the same sense positive resolution advisory. Figure 10-2 shows the routine to determine if the negative of a resolution advisory provides sufficient separation. If negative resolution advisories provide sufficient separation, the NEGATIVE flag is set in the resolution advisory data structure.

When the vertical dimension has been selected for resolution, negative vertical resolution advisories are selected if the vertical predicted separation at the time a pilot responds is greater than the positive resolution advisory altitude separation (ASEP) and the aircraft will not converge to less than ASEP during the projection interval. If both aircraft are maneuvered, negative vertical advisories are explicitly modeled. This is not true if only one aircraft is maneuvered. If only one aircraft is maneuvered, both the "climb" and "descend" advisories will be examined. If the advisory will maneuver that aircraft

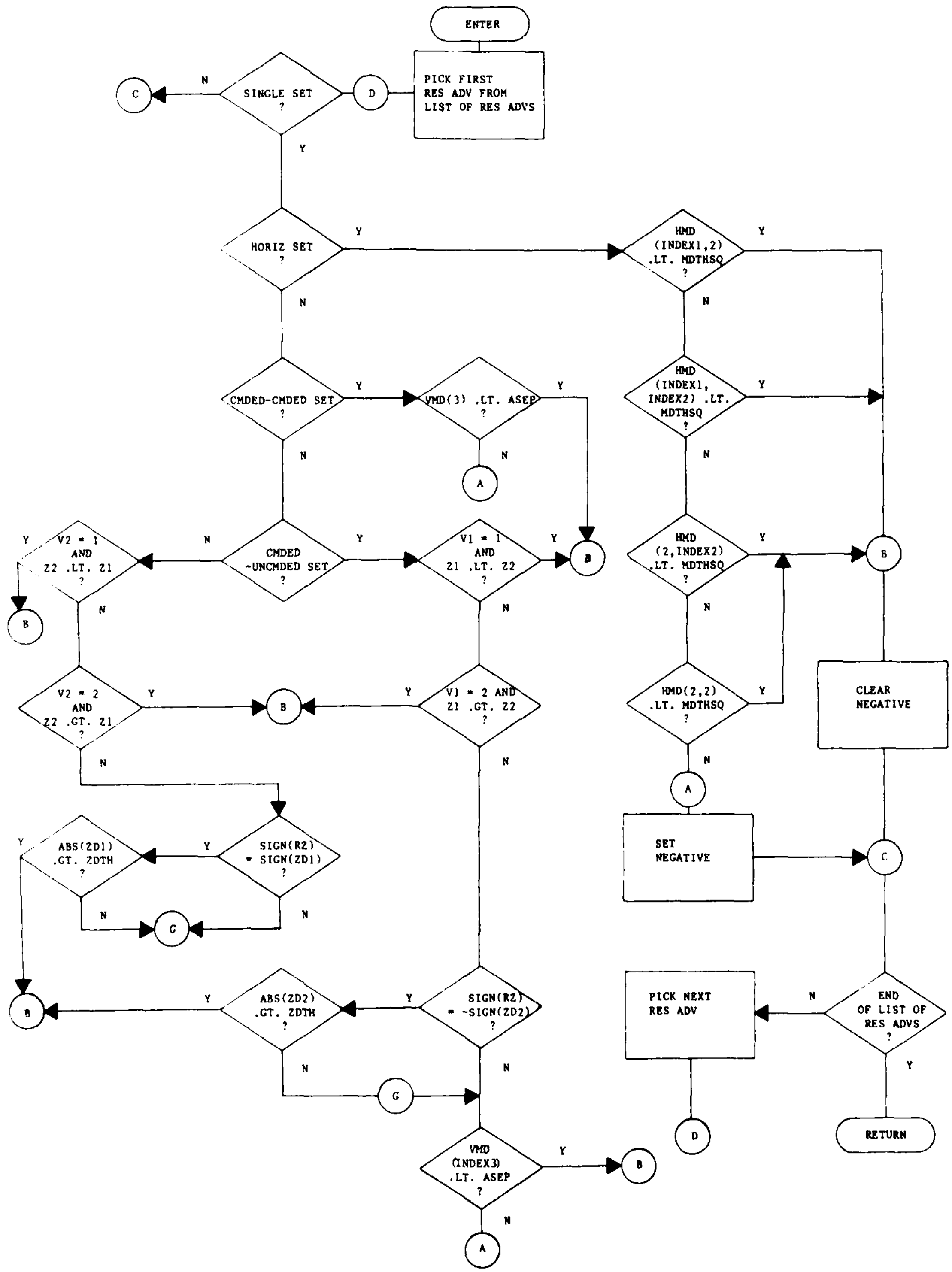


FIGURE 10-2
NEGATIVE RESOLUTION ADVISORY DETERMINATION ROUTINE

into the unmaneuvered aircraft, then the negative of that advisory is not acceptable, since the negative advisory would still allow the aircraft to maneuver into the unmaneuvered aircraft. If the advisory will maneuver the aircraft away from the unmaneuvered aircraft, check the separation achieved by the positive advisory. If the positive sense of the advisory will prevent the aircraft from coming closer than ASEP, then the negative is acceptable, since the negative is essentially a level-off advisory. The negative is acceptable only if the unmaneuvered aircraft does not have a large vertical rate towards the maneuverd aircraft. When the horizontal dimension has been selected for resolution, negative horizontal resolution advisories are selected if the horizontal predicted separation along each of the allowable response paths is greater than the positive resolution advisory horizontal miss distance threshold (MDTHSQ). To check if negative horizontal resolution advisories give sufficient separation, four PSEP values must be examined if both aircraft are maneuvered, and two PSEP values must be examined if only one aircraft is maneuvered.

For both aircraft maneuvered, the predicted separations must all be greater than MDTHSQ if both aircraft, either aircraft or neither aircraft maneuvers. For example, if "turn left"/"turn left" is the advisory set being examined, then the PSEP values for "turn left"/"turn left," "turn left"/"continue straight," "continue straight"/"turn left" and "continue straight"/ "continue straight" must all be greater than MDTHSQ if the NEGATIVE flag is to be set indicating a "don't turn right"/"don't turn right" advisory combination.

If only one aircraft is maneuvered, check the PSEP values of two boxes. If the potential advisory to aircraft one were "turn left," then check the PSEP value of the "turn left"/"continue straight" and "continue straight"/"continue straight" advisories to determine if a "don't turn right" would be a sufficient advisory to aircraft one.

Double dimension advisories are not checked for the possibility of giving negative advisories. When single dimension advisories are checked for negatives being sufficient, always check for positive or negative advisories to both aircraft (assuming both maneuvered). Never give a positive advisory to one aircraft and a negative to the other, except for the one case where the aircraft to receive a "descend" advisory is below ATERN feet AGL.

If any resolution advisory would descend an aircraft that is currently below ATERN feet AGL, then the BELOW1000 flag is set, indicating that the "descend" should be changed to a "don't climb."

The H1, V1, H2, and V2 fields of the selected resolution advisory should be modified, if necessary, because of the NEGATIVE flag or the BELOW1000 flag.

If negative vertical resolution advisories are selected for both aircraft, VSL resolution advisories are evaluated as shown in detail in Figure 10-3.

The desired vertical speed limit is computed based on the current altitude separation, current speeds, expected pilot delay time, and desired separation at the projected collision time. Speed limits are computed for each aircraft assuming that there is no change in the direction and velocity of the other aircraft. To receive a VSL, an aircraft must be maneuvering vertically faster than the minimum rate (MRATE) and the direction of the aircraft's current vertical velocity must be towards the other aircraft.

VSL's are computed individually for each aircraft of the pair. Consequently, only one or both may receive VSL's or different VSL's may be given to each one. The computed VSL is rounded down to 2000 ft/min, 1000 ft/min, or 500 ft/min.

If a VSL resolution advisory is selected, it is assigned to the vertical field in the resolution advisory data structure. Otherwise, a negative vertical resolution advisory is assigned.

After the VSL calculations have been performed, the Domino Routine may be performed. The domino logic projects each of the maneuvered aircraft in the conflict pair as responding to each of the potential resolution advisories. The results of the domino logic are a high priority feature used to evaluate the relative desirability of resolution advisories. If an aircraft in conflict is predicted to be involved in another conflict requiring resolution advisories because of response to a particular resolution advisory, then that resolution advisory is not favored above the other resolution advisories.

After all of the resolution advisories have been evaluated, the resolution advisory that has been given the highest value is chosen. If there are two resolution advisories with the same value, the last feature uses the predicted separation to break the tie.

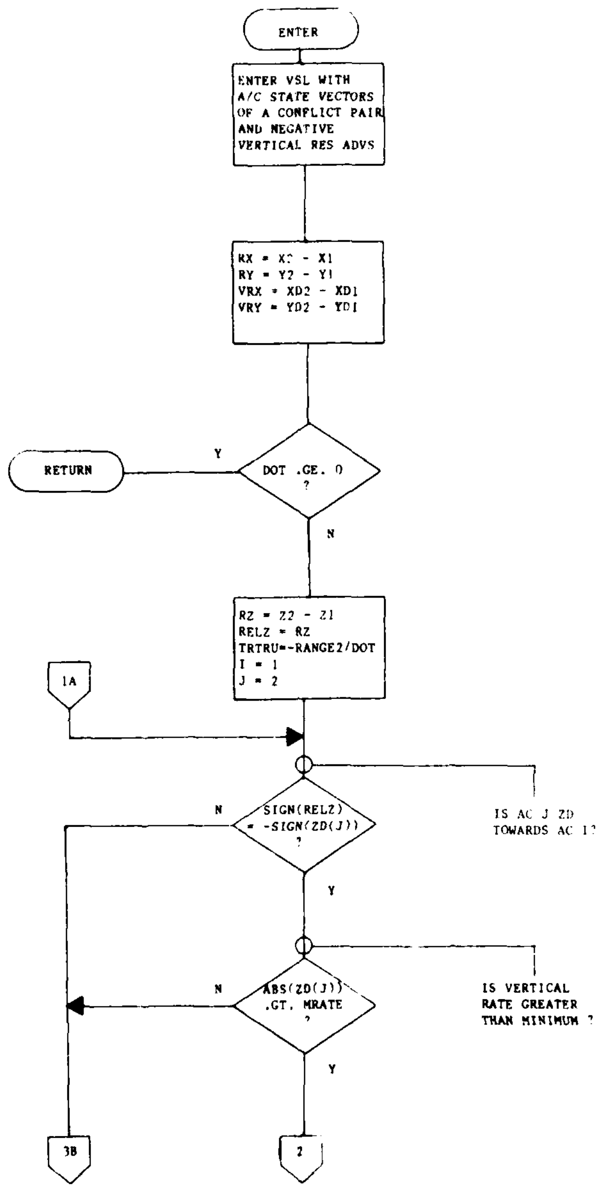


FIGURE 10-3
VERTICAL SPEED LIMIT EVALUATION ROUTINE (Page 1 of 3)

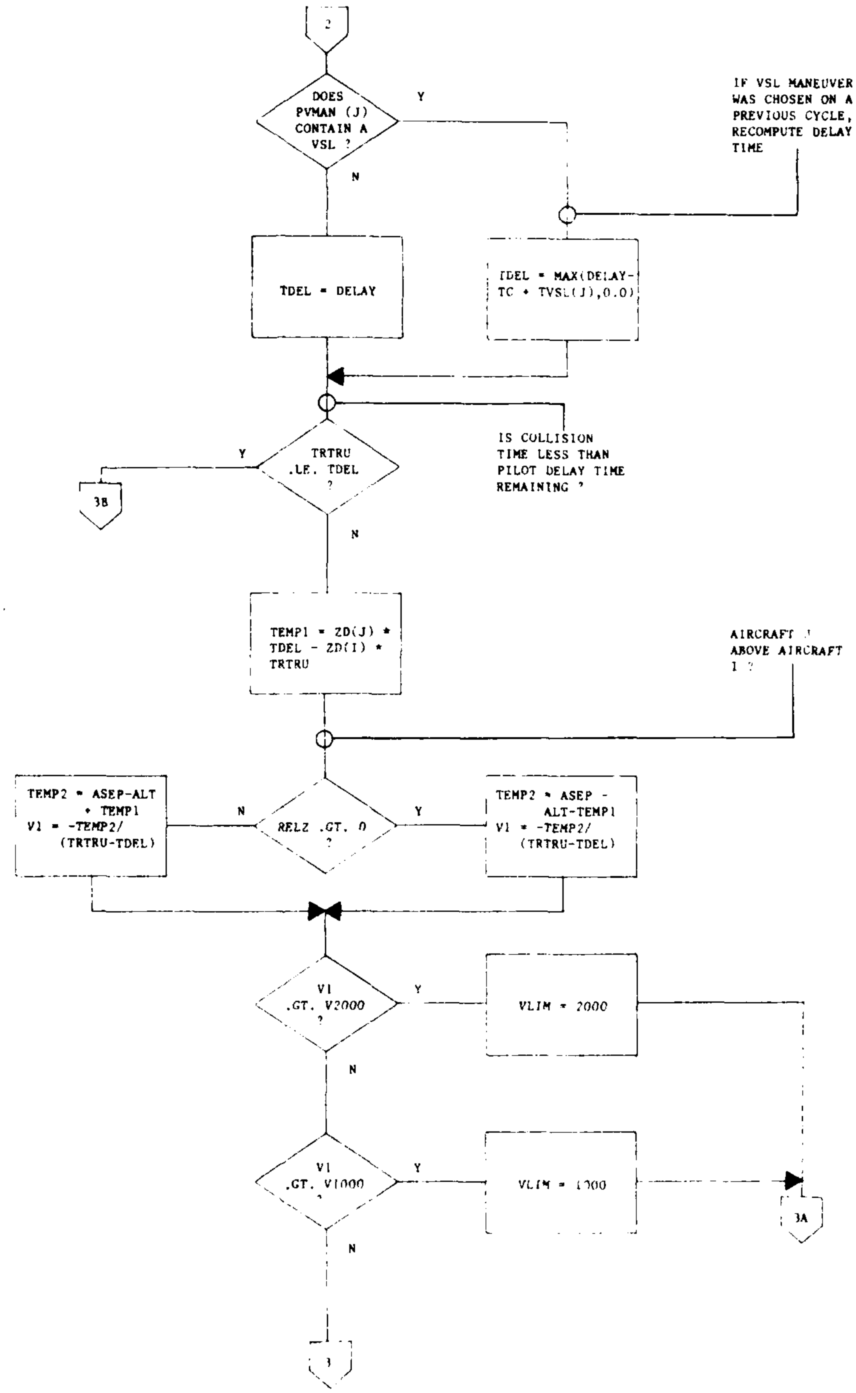


FIGURE 10-3
VERTICAL SPEED LIMIT EVALUATION ROUTINE (Page 2 of 3)

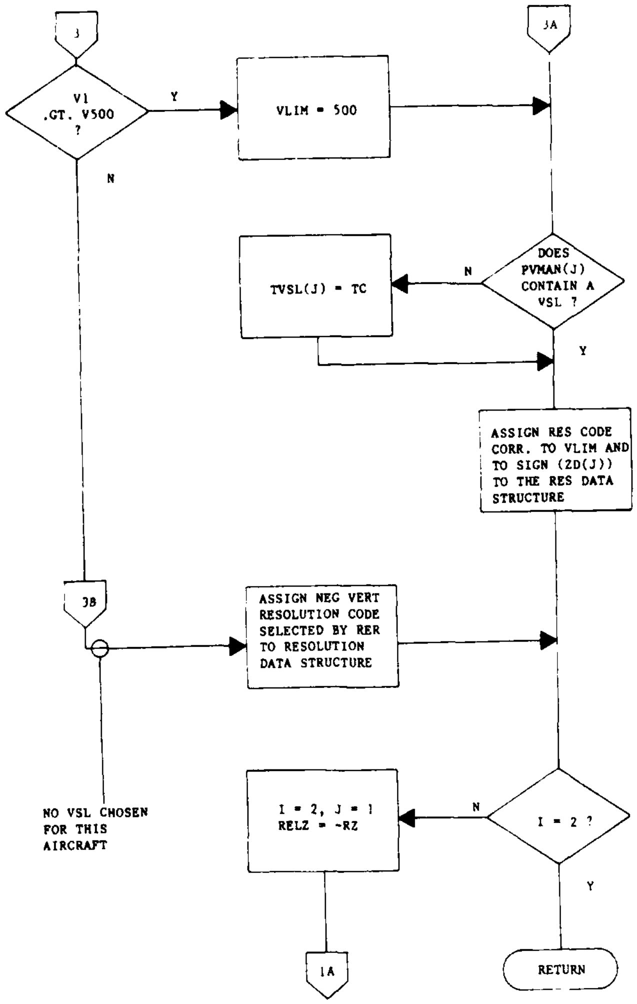


FIGURE 10-3
VERTICAL SPEED LIMIT EVALUATION ROUTINE (Page 3 of 3)

10.1 Predicted Separation Matrix (PSEP)

The PSEP matrix contains the separations that two conflicting aircraft are expected to achieve by obeying resolution advisories. The separations are computed by performing a fast time simulation and modeling the performance of the aircraft. The separation is a weighted three dimensional (3-D) slant range; vertical is weighted VWEGHT to 1.

The PSEP matrix is a 3x3x3 array (see Figure 10-4). The first dimension corresponds to the three horizontal resolution advisories: Turn Left (TL), Continue Straight (CS), and Turn Right (TR), for one of the aircraft. The second dimension corresponds to the same three horizontal resolution advisories for the other aircraft. The third dimension corresponds to the three levels of vertical resolution advisories. The levels of vertical resolution advisories will be explained in more detail later.

Because of the values needed by the negative resolution advisory determination logic and the domino logic, predicted separations for all nine of the horizontal-advisories-only level would normally be computed. The nine predicted separations can be calculated by performing six projections. Each aircraft is projected as turning left, turning right and continuing straight. Then the nine combinations are formed and minimum separations calculated.

While the projected paths for each aircraft are being computed, the appropriate positions are saved in the Resolution Advisory Projected Position (RAPP) Table for the domino logic.

To save from having to compute square roots, the square of the slant range is stored. Slant range is measured in nautical miles and is stored in nmi^2.

Each of the three horizontal resolution advisories for one aircraft combines with those for the other aircraft, giving a total of nine combinations. These nine combinations model all possible horizontal resolution advisories. A pair where both aircraft are to be maneuvered could get the horizontal resolution advisories TR/TR, TR/TL, TL/TR or TL/TL. When only the first aircraft is to be maneuvered, the horizontal resolution advisories TL/CS and TR/CS are considered. Similarly, when only the second aircraft is to be maneuvered, the horizontal resolution advisories CS/TL and CS/TR are considered. An aircraft getting only vertical resolution advisories could be treated as if it

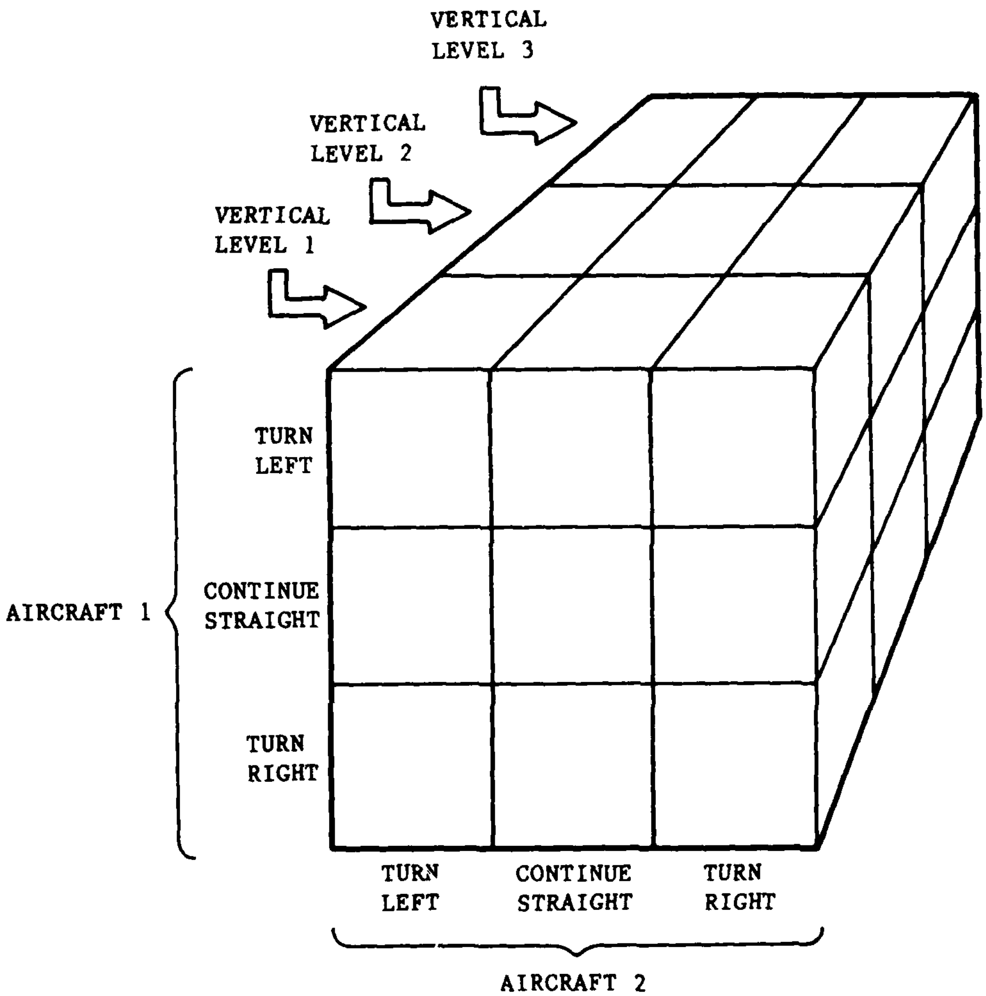


FIGURE 10-4
PSEP MATRIX

were getting a "continue straight". An aircraft obeying a negative horizontal resolution advisory is also modeled as if it were continuing straight. The algorithm to model horizontal maneuvers is presented in Table 10-6.

All nine combinations are not formed when one or both of the aircraft already have resolution advisories in their conflict table entries. In this case, only one or two projected paths need to be computed to fill in two of the horizontal advisory level rows. For example, assume an aircraft has a positive "turn left" advisory in its conflict table entry. In this case, only a "turn left" projection needs to be modeled to be used in determing PSEP values for both the "turn left" and "continue straight" rows. If an aircraft has a negative horizontal advisory, "don't turn left," then two paths must be modeled. These are the "don't turn left" path used for the "continue straight" advisory row of the PSEP matrix and the "turn right" path for the "turn right" row.

The vertical dimension must be handled differently. It would be prohibitively expensive to compute all possible vertical resolution advisories and to combine them with the nine pairs of horizontal resolution advisories. Fortunately, it isn't necessary to compute all possible vertical resolution advisories; only some of them are sensible. For maneuvered-maneuvered pairs, the "eight second rule" is used as previously described. No other vertical resolution advisories need to be considered. For an unmaneuvered-maneuvered pair, vertical resolution advisories don't have to be considered for the unmaneuvered aircraft, but both "climb" and "descend" for the maneuvered aircraft must be investigated.

It seems best to handle maneuvered-maneuvered pairs and unmaneuvered-maneuvered pairs separately. The three levels of vertical resolution advisories will mean one thing when both of the aircraft are maneuvered and something different when one of the aircraft is unmaneuvered.

For pairs where both aircraft are to be maneuvered, level one will correspond to both aircraft being projected ahead with their current vertical rate. Level two will correspond to the vertical resolution advisories picked by the "eight second rule," and level three will correspond to the negative of these resolution advisories. Note that negative vertical resolution advisories must be explictly computed.

For pairs where only one of the aircraft is maneuvered, level one will have the same meaning as above. Level two will correspond to the maneuvered aircraft getting a "descend," and

TABLE 10-6

ALGORITHM TO MODEL MANEUVERS

PARAMETERS

```
V1  - Velocity of aircraft 1
V2  - Velocity of aircraft 2
g   - Acceleration due to gravity
ZDF - Final vertical rate
```

TURN RATE

```
W1 = g* TAN (BANK ANGLE) /V1
W2 = g* TAN (BANK ANGLE) /V2
```

CONSTANTS FOR MANEUVER ALGORITHMS

```
SA    = SIN (W* TIME INTERVAL)
CA    = COS (W* TIME INTERVAL)
A     = (1.0 - CA) /W
B     = SA / W
ACCEL = ACCELC*TIME INTERVAL
          if ZDF .GT. ZD
      = -ACCELD*TIME INTERVAL
          if ZDF .LT. ZD
```

TO ADVANCE AIRCRAFT THROUGH DELAY

```
X'  = X + XD*DELAYH
Y'  = Y + YD*DELAYH
Z'  = Z + ZD*DELAYV
```

TO ADVANCE AIRCRAFT THROUGH A LEFT TURN

```
X'  = X - (YD*A) + (XD*B)
Y'  = Y + (XD*A) + (YD*B)
XD' = (XD*CA) - (YD*SA)
YD' = (XD*SA) + (YD*CA)
```

TO ADVANCE AIRCRAFT THROUGH A RIGHT TURN

```
X'  = X + (YD*A) + (XD*B)
Y'  = Y - (XD*A) + (YD*B)
XD' = (XD*CA) + (YD*SA)
YD' = -(XD*SA) + (YD*CA)
```

TO ADVANCE AIRCRAFT DURING VERTICAL ACCELERATION

```
If ABS(ZDF-ZD) .GT. ABS(ACCEL)
then ZD' = ZD + ACCEL
else ZD' = ZDF
Z' = Z + ZD' * TIME INTERVAL
```

TABLE 10-6

ALGORITHM TO MODEL MANEUVERS
(Continued)

RELATIVE RANGE AND VELOCITY (VERTICAL WEIGHTED)

```
RX  = X2 - X1
RY  = Y2 - Y1
RZ  = (Z2 - Z1)*VWEGHT
VRX = XD2 - XD1
VRY = YD2 - YD1
VRZ = (ZD2 - ZD1)*VWEGHT
```

VERTICAL DOT TEST

```
DOT  = RZ*VRZ
```

HORIZONTAL DOT TEST

```
DOT = RX*VRX + RY*VRY
```

THREE DIMENSIONAL DOT TEST (VERTICAL WEIGHTED)

```
DOT = RX*VRX + RY*VRY + RZ*VRZ
```

THREE DIMENSIONAL MISS DISTANCE (VERTICAL WEIGHTED)

$$MD2 = \frac{(RY*VRZ - RZ*VRY)^2 + (RZ*VRX - RX*VRZ)^2 + (RX*VRY - RY*VRX)^2}{VRX^2 + VRY^2 + VRZ^2}$$

MD = SQRT (MD2)

HORIZONTAL MISS DISTANCE

$$MD2 = \frac{(RX*VRY - RY*VRX)^2}{VRX^2 + VRY^2}$$

MD = SQRT (MD2)

TABLE 10-6

ALGORITHM TO MODEL MANEUVERS
(Concluded)

BANK ANGLE	-	System parameter (BANKA) for the bank angle to be modeled.
TURN ANGLE	-	System parameter (TURNA) for the angle that the slower aircraft is to be turned through.
TIME INTERVAL	-	System parameter (TIMINT) for the time interval for each iteration of the algorithm to advance the aircraft through a maneuver.
DELAY	-	Predicted uplink delay plus pilot's delay in response to resolution advisories.
DELAYH1, DELAYH2	-	Predicted delay before this aircraft responds to horizontal resolution advisories. Set to zero if the aircraft presently has a positive resolution advisory in this dimension, otherwise, set to DELAY.
DELAYV1, DELAYV2	-	Predicted delay before this aircraft responds to vertical resolution advisories. Set to zero if the aircraft presently has a positive resolution advisory in this dimension, otherwise, set to DELAY.

$$PR = \frac{XDF*(XS-XF) + YDF*(YS-YF)}{VF}$$

$$LL = \frac{PR + \text{Diameter of Turn of Slower Aircraft}}{VF}$$

$$UL = PR/(VF - VS)$$

where PR - current range projected onto velocity vector of faster aircraft

VF	-	velocity of faster aircraft
XDF,YDF	-	X, Y components of VF
XS, YS	-	coordinates of slower aircraft
XF, YF	-	coordinates of faster aircraft
VS	-	velocity of slower aircraft.

level three will correspond to a "climb" for that aircraft. The unmaneuvered aircraft will be projected ahead with current vertical rate for all three levels. Negative vertical resolution advisories are not explictly modeled. The definition of the three vertical levels for all of the above cases is provided in Table 10-7.

The only exception to the above rules is when it is desired to model a descent for an aircraft below ATERN feet AGL. In this case, model a "don't climb" instead.

While collecting the 3-D slant range, record the minimum two dimensional Horizontal Miss Distance (HMD) and the minimum Vertical Miss Distance (VMD). The 3-D closest approach, horizontal closest approach and vertical closest approach may occur at different times.

The Horizontal Miss Distance (HMD) array is a 3x3 matrix. Each element in the HMD matrix correlates with the appropriate element of the first level of the PSEP matrix.

The Vertical Miss Distance (VMD) array is a three element array. Each element correlates with the one element in each level of the PSEP matrix that models vertical only resolution advisories.

To generate the PSEP matrix, a fast time simulation is performed. The expected response of the aircraft to the resolution advisory is modeled and the minimum separation between the aircraft is measured. The aircraft are modeled to maneuver for a fixed time interval, MANTM. MANTM is computed for each encounter as a function of the velocities of the maneuvered aircraft.

When one of the aircraft is already receiving (in its conflict table entry) a resolution advisory, the fast time simulation of that aircraft's projected path will be handled slightly differently.

The difference is that the aircraft is assumed to be already maneuvering in response to the resolution advisory in the conflict table entry. If a horizontal advisory "turn left" is in the conflict table entry from another conflict, then the aircraft's paths when modeling "continue straight" and "turn left" are exactly the same.

In computing the predicted separation between two aircraft in response to a resolution advisory, each aircraft's projected position and velocity must be determined at intervals along its

TABLE 10-7

PSEP VERTICAL LEVELS

COMMANDED-COMMANDED

LEVEL 1:	Project both aircraft ahead with their current vertical rate.
LEVEL 2:	Pick vertical using "eight second rule," project each aircraft ahead following positive of vertical resolution advisory.
LEVEL 3:	Pick vertical using "eight second rule," project each aircraft ahead following negative vertical resolution advisory.

UNCOMMANDED-COMMANDED

LEVEL 1:	Project both aircraft ahead with their current vertical rate.
LEVEL 2:	Descent for CMDED*, project UNCMDED ahead at current vertical rate.
LEVEL 3:	Climb for CMDED, project UNCMDED ahead at current vertical rate.

* CMDED - maneuvered (commanded); UNCMDED - unmaneuvered (uncommanded)

predicted path. As these predicted positions and velocities are determined, certain of these values are saved in the Resolution Advisory Projected Position (RAPP) Table (Figure 10-5) to be used by the Domino Routine (see Section 10.3). The RAPP table is initialized to all zeroes before the PSEP projections are calculated. This is done so that if the domino logic tries to use values that have not been calculated, this condition can be recognized and the projection calculations may then be performed.

MANTM is calculated in the following manner. First, a vertical maneuver time (VMANTM) is calculated. If the two aircraft are initially converging at a rate greater than ZDTH, VMANTM is computed to be the time required for the two aircraft to reach co-altitude. If the aircraft are diverging, or converging at a rate less than ZDTH, VMANTM is set to zero.

Next, a horizontal maneuver time (HMANTM) is calculated according to the following procedure. If only one aircraft is to be maneuvered, HMANTM is initially set to the value which will model the maneuvered aircraft through a turn angle (TURNA). If both aircraft are to be maneuvered, the initial value of HMANTM should model the two aircraft through a combined angle of TURNA. To this initial value of HMANTM should be added the value of the DELAY parameter. Next, if the horizontal speed ratio between the two aircraft is greater than 2:1, a Lower Limit (LL) and an Upper Limit (UL) are applied to HMANTM. These are computed according to the formulas in Table 10-6. The lower limit is applied to HMANTM only if the slower aircraft is to be maneuvered.

Finally, MANTM is chosen to be the larger of VMANTM and HMANTM. The absolute lower and upper limits of MTLL and MTUL are applied to the value of MANTM selected. The value of MANTM is a value for the total projection time in response to a resolution advisory. That is, any delay time is included in MANTM so that the normal modeled response is for an aircraft to continue on its present course for DELAY seconds and then maneuver for (MANTM - DELAY) seconds. However, if an aircraft has already received the resolution advisory to be modeled in either dimension, no delay is assumed, and the maneuver is modeled for the entire duration of MANTM.

For some geometries the aircraft will still be converging at the end of MANTM. For these geometries, the measured minimum separation will be larger than the true closest approach. Determine if two aircraft are converging by applying the DOT

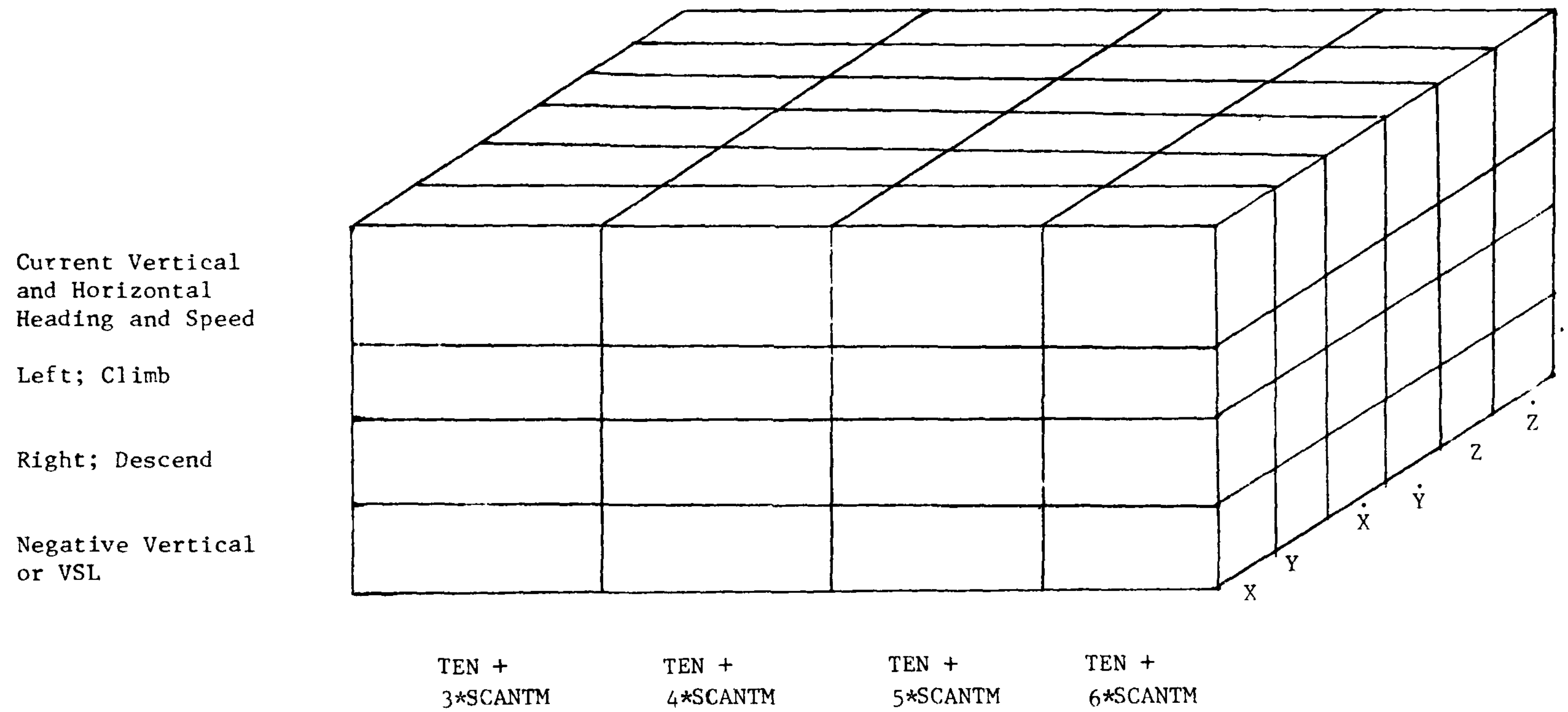


FIGURE 10-5
RESOLUTION ADVISORY PROJECTED POSITION (RAPP) TABLE

test shown in Table 10-6. If the value computed for DOT is negative, then the aircraft are converging. The 3-D DOT test should be applied when generating the PSEP matrix. The vertical and horizontal tests should be applied for generating the VMD and HMD matrices.

The VMD matrix is used for determining if negative resolution advisories give sufficient separation. Do not issue negative vertical resolution advisories that will allow the aircraft to converge. Set any entry in VMD to zero if the vertical DOT test indicates convergence. Likewise, if the three-dimensional DOT test shows convergence at MANTM, then PSEP is set to zero if the resolution advisory set contains a horizontal maneuver. For vertical maneuvers only, PSEP is calculated in this instance by the three-dimensional miss distance formula given in Table 10-6. Similarly, if the horizontal DOT test shows convergence at MANTM, then HMD is computed from the horizontal miss distance formula for the center element of the HMD matrix (no horizontal maneuvers) or set to zero for any other element (at least one horizontal maneuver).

10.2 Feature Evaluation

The resolution advisories are evaluated by applying a number of sequential tests. The outcome of the tests may depend on the geometry of the encounter, the speeds of the aircraft, the predicted separation or many other factors. Table 10-8 shows these tests in order of precedence. Table 10-9 provides the logic for the resolution advisory compatibility and reinforcement checks.

The data structures are general enough to allow an efficient implementation in most programming languages. Any implementation should be flexible enough to allow new tests to be added and the list reordered without a major redesign.

In one possible implementation, the tests would be individual routines that would operate on the list of resolution advisories. Each test would have a weight associated with it; the most important test would have the highest weight. These weights would be stratified so that the weight of a test would be greater than the sum of the weights for the less important tests. This could be accomplished by using sequential powers of two for the weights. If a resolution advisory passed a test, its VALUE field would be increased by the weight for that test. The resolution advisory with the highest number in its VALUE field would be considered the best resolution advisory.

TABLE 10-8

RESOLUTION ADVISORY EVALUATION CRITERIA

DELIVERABLE - Favor this resolution advisory if the predicted 3-D separation is greater than or equal to the predicted separation for the pair if no resolution advisories were given.

DIMENSION AVAILABLE - Favor single horizontal (vertical) resolution advisories if ACIDH (ACIDV) is null and no other aircraft is receiving a horizontal (vertical) advisory because of this aircraft. Favor single horizontal (vertical) resolution advisories if the aircraft is already receiving this advisory. Do not favor single horizontal (vertical) resolution advisories if either of the aircraft is receiving an advisory that is incompatible with this advisory (Table 10-9).

Favor doubles if the conditions for both favor horizontal and favor vertical are satisfied.

NEITHER DOMINO - Favor this resolution advisory if neither aircraft is predicted to be in another conflict because of this resolution advisory.

ONE DOMINO - Favor this resolution advisory if only one aircraft is predicted to be in another conflict because of this resolution advisory.

PSEP SEP1 - Favor this resolution advisory if the predicted 3-D separation is greater than SEP1. (Vertical weighted).

FAR FROM RADAR - Favor single vertical advisories if either of the aircraft is further than RDISTR from the radar (i.e., SLREPS .GT. RDISTR).

NEGATIVE SUFFICES - Favor if advisory satisfies the criteria for negative resolution advisory.

NEGATIVE DOES NOT REVERSE MANEUVER - Favor if advisory is negative, the pilot is maneuvering and the negative advisory will not force him to stop that maneuver. Turn sensing and vertical rate sensing are used to detect a maneuver.

BIGGEST PSEP FOR NEGATIVE - Favor the advisory giving the biggest predicted separation and has NEGATIVE set.

TABLE 10-8

RESOLUTION ADVISORY EVALUATION CRITERIA
(Continued)

FAST UNCMDED/SLOW CMDED - Favor double resolution advisories for a CMDED-UNCMDED encounter if the speed ratio of the UNCMDED to the CMDED is at least VRATIO, the UNCMDED is converging with a vertical rate in excess of ZDTH, and the track crossing angle is between TXTH1 and TXTH2.

UNCMDED WITH LARGE VERTICAL RATE - Favor horizontal and double resolution advisories if the UNCMDED is converging in altitude, with a vertical rate in excess of ZDTH.

NO LEVEL OFF TIME FOR VERTICALS - Favor horizontal and double resolution advisories if the aircraft are between TV1 and TV2 seconds from vertical crossing.

DETERIORATION - Favor double resolution advisories if the pair has satisfied the deterioration logic criteria. (PATH=1)

AIRCRAFT ON FINAL APPROACH - Favor single horizontal resolution advisories for an aircraft in the Final Approach Zone (FAZ set) with a ground speed of less than VFAST.

PATH DEPENDENT - Favor single resolution advisories for initial resolution advisory selection and transition. (PATH=0)

PSEP SEP2 - Favor resolution advisories where predicted 3-D separation is greater than SEP2 (vertical weighted.)

COMPATIBLE WITH TURN - Favor advisories where horizontal part of advisory is not the opposite of a turn sensed by the tracker.

BIG VERTICAL MISS DISTANCE - Favor vertical and double resolution advisories if the existing vertical miss distance is at least ASEPV.

BIG HORIZONTAL MISS DISTANCE - Favor horizontal and double resolution advisories if the square of the projected horizontal miss distance is at least MDHSQ.

SPEED CHECK - Favor vertical and double advisories if either maneuvered aircraft has a speed greater than VFAST. Favor horizontal and double resolution advisories if all maneuvered aircraft (one or both aircraft) have speeds below VSLOW.

TABLE 10-8

RESOLUTION ADVISORY EVALUATION CRITERIA
(Concluded)

REINFORCES PRIOR RESOLUTION ADVISORIES - Favor advisory that has the same sense as the advisory given on the previous scan. A double advisory given after a single advisory is compatible if it includes that single advisory (see Table 10-9).

REINFORCES TURN - Favor advisory when horizontal part of the advisory reinforces a turn sensed by the tracker.

BIGGEST PSEP - For all resolution advisories (single horizontal, single vertical, double) favor the advisory with the largest predicted 3-D separation.

TABLE 10-9

PREVIOUS RESOLUTION ADVISORY/NEW RESOLUTION ADVISORY COMPATIBILITY AND REINFORCEMENT

Compatibility

Previous Res Adv / New Res Adv	TL	TR	DTL	DTR	DTL& DTR	CL	DCL/ LIMCL	DES	DDES/ LIMDES	DCL& DDES	NO RES ADV
TL	1	0	0	1	0	1	1	1	1	1	1
TR	0	1	1	0	0	1	1	1	1	1	1
DTL	0	1	1	1	1	1	1	1	1	1	1
DTR	1	0	1	1	1	1	1	1	1	1	1
CL	1	1	1	1	1	1	0	0	1	0	1
DCL/LIMCL	1	1	1	1	1	0	1	1	1	1	1
DES	1	1	1	1	1	0	1	1	0	0	1
DDES/LIMDES	1	1	1	1	1	1	1	0	1	1	1
NO RES ADV	1	1	1	1	1	1	1	1	1	1	1

1 = Compatible, 0 = Incompatible
Double resolution advisories (e.g., climb and turn right) are individually tested.
Both parts must be compatible.

Reinforcement

Previous Res Adv / New Res Adv	TL	TR	DTL	DTR	DTL& DTR	CL	DCL/ LIMCL	DES	DDES/ LIMDES	DCL& DDES	NO RES ADV
TL	1	0	0	1	0	0	0	0	0	0	0
TR	0	1	1	0	0	0	0	0	0	0	0
DTL	0	1	1	0	1	0	0	0	0	0	0
DTR	1	0	0	1	1	0	0	0	0	0	0
CL	0	0	0	0	0	1	0	0	1	0	0
DCL/LIMCL	0	0	0	0	0	0	1	1	0	1	0
DES	0	0	0	0	0	0	1	1	0	0	0
DDES/LIMDES	0	0	0	0	0	1	0	0	1	1	0
NO RES ADV	0	0	0	0	0	0	0	0	0	0	0

To reduce computation time, the list could be pruned after some of the tests. For example, the test that decides whether to favor single or double resolution advisories is guaranteed to cut the list to half of its size, if all of the previous tests are equal. By eliminating all of the resolution advisories that are not tied with the highest value, the amount of computer processing time could be reduced. Whether or not this savings is signficant depends on the implementation.

Domino logic is effectively one feature. However, two flags are controlled by the outcome of tne domino checks. The most desirable situation, and therefore the higher priority of the domino flags, is for neither aircraft to be predicted as being involved in a domino conflict because of the subject resolution advisories. The next priority flag is set if only one aircraft is predicted to be in a domino conflict because of its resolution advisory. The remaining possibilities are that both aircraft are predicted to be in a domino conflict because of this resolution advisory and domino logic is not performed for this pair of aircraft. In these two cases, neither of the domino flags is set.

If there are no resolution advisories with both the Deliverable and Dimension Available Features set, then call the Multi-aircraft Resolution Routine, described in Section 9.5. If only one resolution advisory pair has the Dimension Available Feature set, then the domino logic checks would not be performed.

10.3 Domino Routine

When an aircraft is given a resolution maneuver, it is possible, that by executing tnat maneuver, the aircraft will be directed into a conflict requiring resolution advisories with another aircraft. This type of conflict, caused by a resolution maneuver, is called a domino conflict. If tne second conflict begins before tne first conflict is resolved, then there is a multi-aircraft conflict. It is always desirable to avoid domino created multi-aircraft conflicts, if at all possible. A way to avoid a domino caused multi-aircraft conflict is to model an aircraft's response to a resolution maneuver, and determine if a conflict requiring resolution advisories is created with another

aircraft during the time the aircraft is responding to the resolution advisory. Then, if there is more than one set of acceptable resolution advisories for a pair of aircraft, the best set of resolution advisories that does not cause a domino multi-aircraft conflict should be the set of resolution advisories chosen. Logic that performs the checks for detecting a domino caused multi-aircraft conflict is called the domino logic and is performed by the Domino Routine.

The Domino Routine is called by the RER during evaluation of the features. Figure 10-1 shows the logical placement of the domino logic in RER. The feature evaluation logic determines if the domino logic should be called. There is one case when the RER logic determines that domino need not be performed: This occurs if, after determining the status of the Deliverable and Dimension Available Features, there is only one resolution advisory remaining.

Figure 10-6 is the description of the Domino Routine. The domino logic must determine all the possible resolution advisories available to each aircraft. The potential resolution advisories are needed by the Domino Coarse Screen Routine (Section 10.3) to determine the extent of the search limits. This routine selects all aircraft that are within the search limits and creates a Potential Domino Conflict List for each of the aircraft requiring resolution advisories.

To determine if a given resolution advisory will cause an aircraft to come in conflict with another aircraft, the aircraft's path in response to the resolution advisory must be modeled. This was done when the PSEP calculations were performed. The projected positions and velocities were stored in the Resolution Advisory Projected Position (RAPP) Table (Figure 10-5).

After modeling an aircraft's response to a resolution advisory, the maneuvered aircraft's position and velocity at four SCANTM intervals after the maneuver has begun are compared to the linearly projected positions and velocities of unmaneuvered aircraft from the Potential Domino Conflict List using a shortened detection logic. (Any aircraft on the potential domino list receiving a resolution advisory will be modeled as responding to that resolution advisory with no response delay). Since the only concern is for a conflict requiring resolution advisories being created, the resolution advisory checks are the only checks of the detection logic performed. If a domino conflict is determined with any aircraft on the Potential Domino Conflict List, then the remainder of the list need not be checked for another domino conflict for the same resolution advisory. The subject

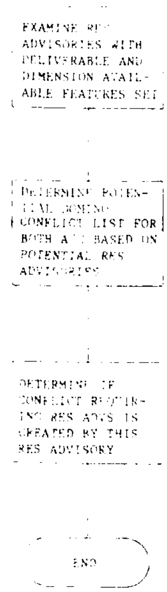


FIGURE 10-6
DESCRIPTION OF DOMINO ROUTINE

AD-A094 195 MITRE CORP MCLEAN VA METREK DIV F/G 1/5

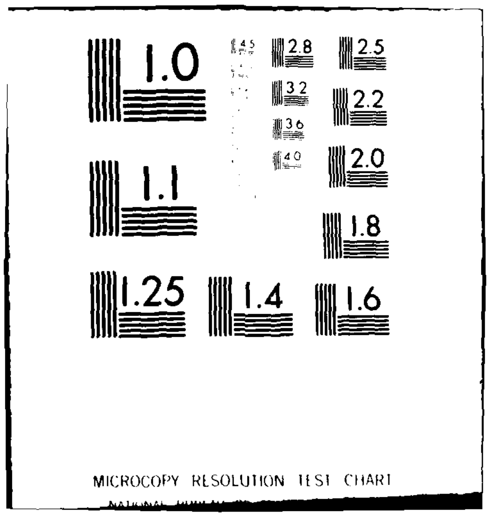
AUTOMATIC TRAFFIC ADVISORY AND RESOLUTION SERVICE (ATARS) MULTI--ETC(U)

OCT 80 R H LENTZ, W D LOVE, N S MALTHOUSE DOT-FA80WA-4370

UNCLASSIFIED MTR-80W00100-REV-1 FAA-RD-80-3-REV-1 NL

5 OF 6

AD A
094195


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6
MICROCOPY RESOLUTION TEST CHART

resolution advisory is flagged as causing a domino. The domino checks then begin for the next resolution advisory.

Figure 10-7 is the detailed flow chart of the Domino Routine. The first thing done in the domino logic is to determine which aircraft is maneuvered. This can be done by examining the CMDED-UNCMDED and the UNCMDED-CMDED flag of the first potential resolution advisory. If one of the aircraft is not maneuvered, then the appropriate NOCMD flag is set. These flags are used in the Domino Coarse Screen Routine.

The resolution advisory flags are set by cycling through all the potential resolution advisories. The potential resolution advisory flags are shown in Table 10-10. There is only one flag for negative horizontal resolution advisories, since a "don't turn left" and "don't turn right" are both equivalent to "continue straight." Also, since there may be at most one VSL resolution advisory per aircraft, there need be only one flag, with the value of the flag indicating the speed limit rate.

Any resolution advisories in an aircraft's conflict table entry do not have to explicitly be accounted for, since these advisories are accounted for in the modeled paths for the potential advisories. That is, if an aircraft has a "turn left" in its conflict table entry, a potential resolution advisory for that aircraft will be "turn left." If the potential resolution advisory is "don't turn right" or there is no potential horizontal resolution advisory, then that aircraft's "continue straight" path will actually be projected as responding to the "turn left." In either case, the effect of advisories in the conflict table is taken into account.

The Domino Coarse Screen Routine (Figure 10-8) determines a list of potential domino conflict aircraft for each of the aircraft that is to receive a resolution advisory. If there are no potential conflict aircraft for the first aircraft, the routine branches to the processing of the second aircraft. Otherwise, call the Domino Detection Routine for the first aircraft. The Domino Detection Routine checks each potential resolution advisory for causing a domino conflict. The target aircraft's projected positions and velocities in response to the potential resolution advisory have been determined. These positions and velocities are then paired with linear projections of each aircraft from the Potential Domino Conflict List. If a domino conflict is predicted, the remainder of the aircraft from the Potential Domino Conflict List are not checked against the same resolution advisory.

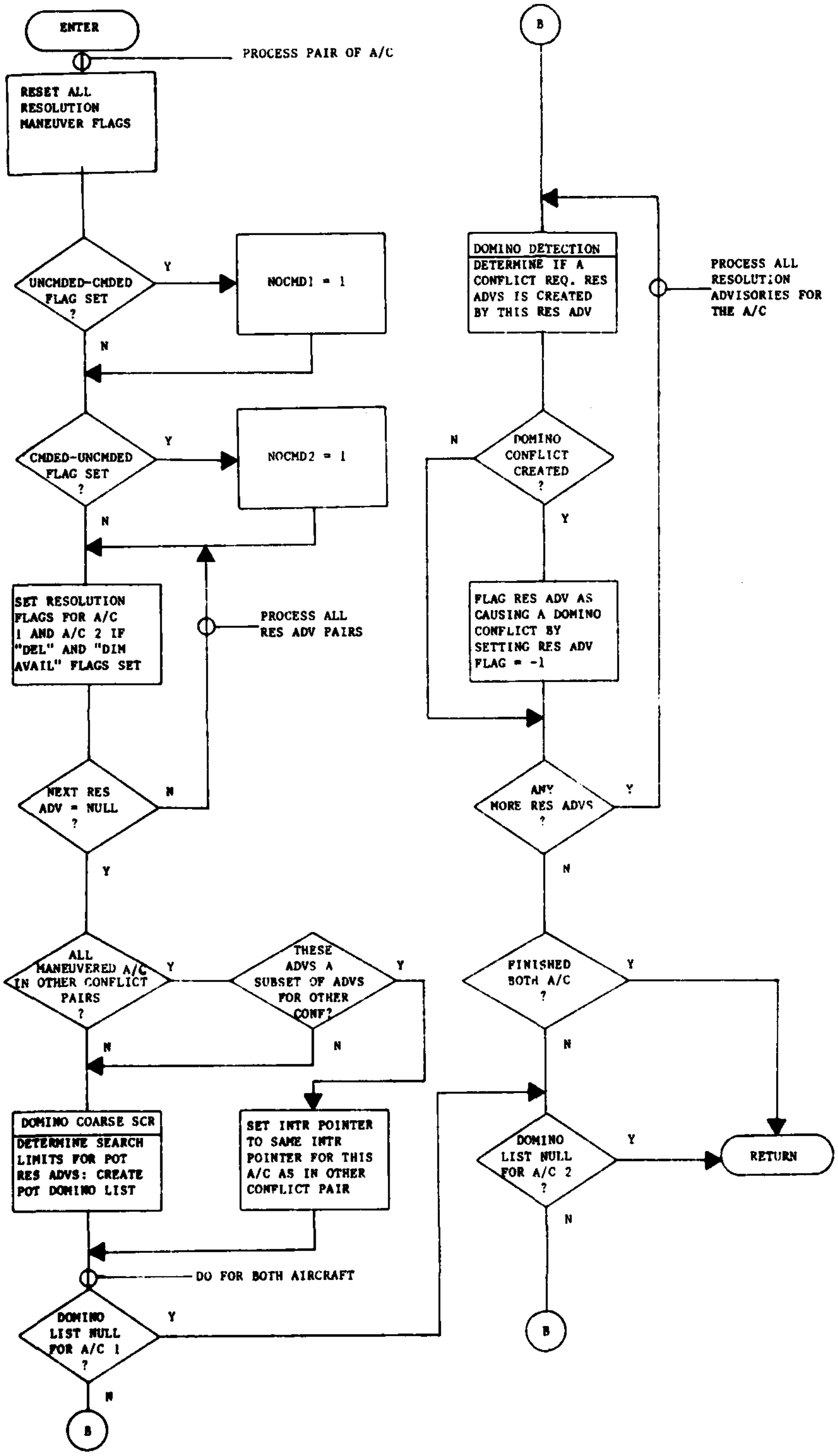


FIGURE 10-7
DOMINO ROUTINE

TABLE 10-10

POTENTIAL RESOLUTION ADVISORY FLAGS

FLAG NAME	SETTINGS	DEFINITION
LEFT1, LEFT2	-1	Domino caused by left turn
	0	No left turn
	1	Potential left turn
RGHT1, RGHT2	-1	Domino caused by right turn
	0	No right turn
	1	Potential right turn
NLNR1, NLNR2	-1	Domino caused by don't turn left and/or don't turn right
	0	No negative horizontal resolution advisory
	1	Potential don't turn left and/or don't turn right
NOCMD1, NOCMD2	0	At least one resolution advisory
	1	No potential resolution advisories for this aircraft
CL1, CL2	-1	Domino caused by climb
	0	No climb
	1	Potential climb
DES1, DES2	-1	Domino caused by descend
	0	No descend
	1	Potential descend
NCL1, NCL2	-1	Domino caused by don't climb
	0	No don't climb
	1	Potential don't climb
NDS1, NDS2	-1	Domino caused by don't descend
	0	No don't descend
	1	Potential don't descend

TABLE 10-10

POTENTIAL RESOLUTION ADVISORY FLAGS
(Concluded)

FLAG NAME	SETTINGS	DEFINITION
VSL1, VSL2	-1	Domino caused by vertical speed limit
	0	No potential VSL
	1	Potential limit climb to 500 fpm
	2	Potential limit climb to 1,000 fpm
	3	Potential limit climb to 2,000 fpm
	4	Potential limit descend to -500 fpm
	5	Potential limit descend to -1,000 fpm
	6	Potential limit descend to -2,000 fpm
LTCL1, LTCL2	-1	Domino caused by left turn, climb
	0	No left turn, climb
	1	Potential left turn, climb
RTCL1, RTCL2	-1	Domino caused by right turn, climb
	0	No right turn, climb
	1	Potential right turn, climb
LTDS1, LTDS2	-1	Domino caused by left turn, descend
	0	No left turn, descend
	1	Potential left turn, descend
RTDS1, RTDS2	-1	Domino caused by right turn, descend
	0	No right turn, descend
	1	Potential right turn, descend

The suffix 1 or 2 denotes the first or second aircraft in the pair record.

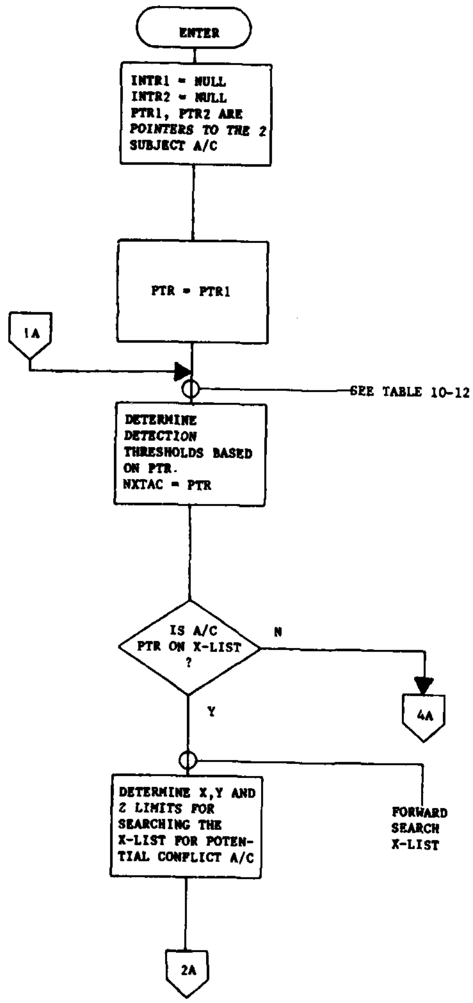


FIGURE 10-8
DOMINO COARSE SCREEN ROUTINE (Page 1 of 7)

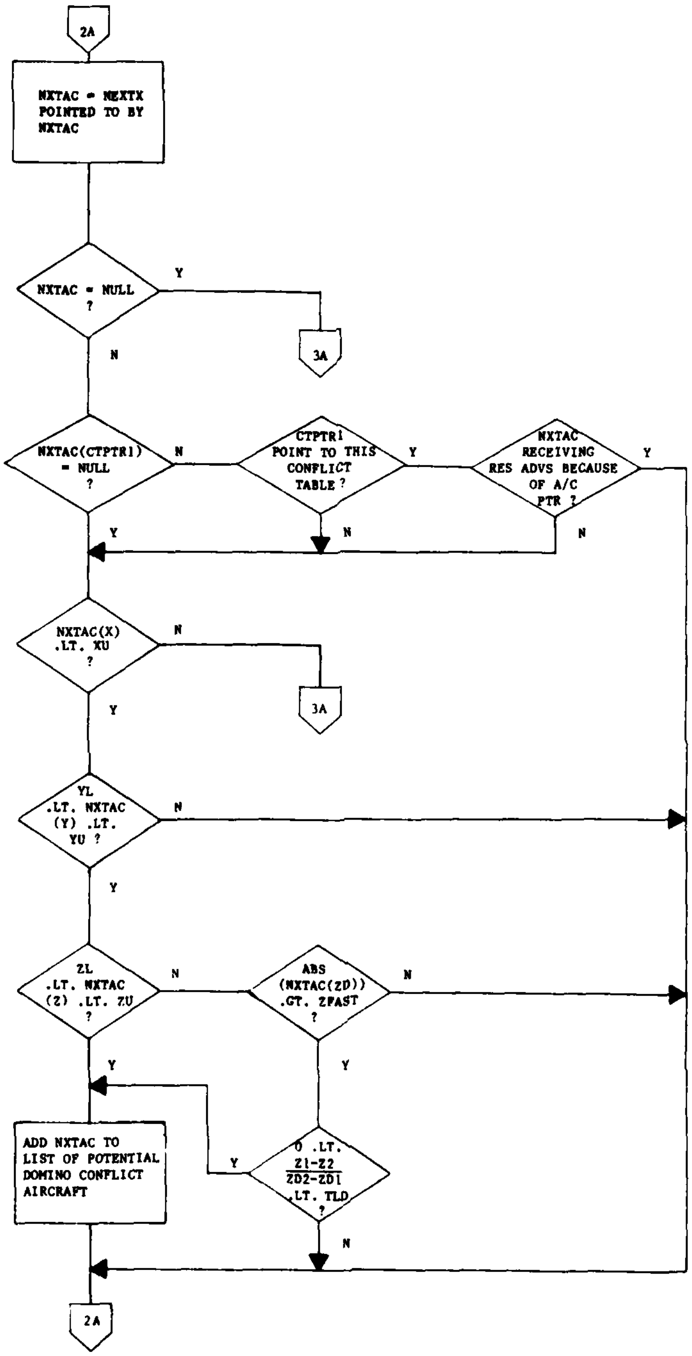


FIGURE 10-8
DOMINO COARSE SCREEN ROUTINE (Page 2 of 7)

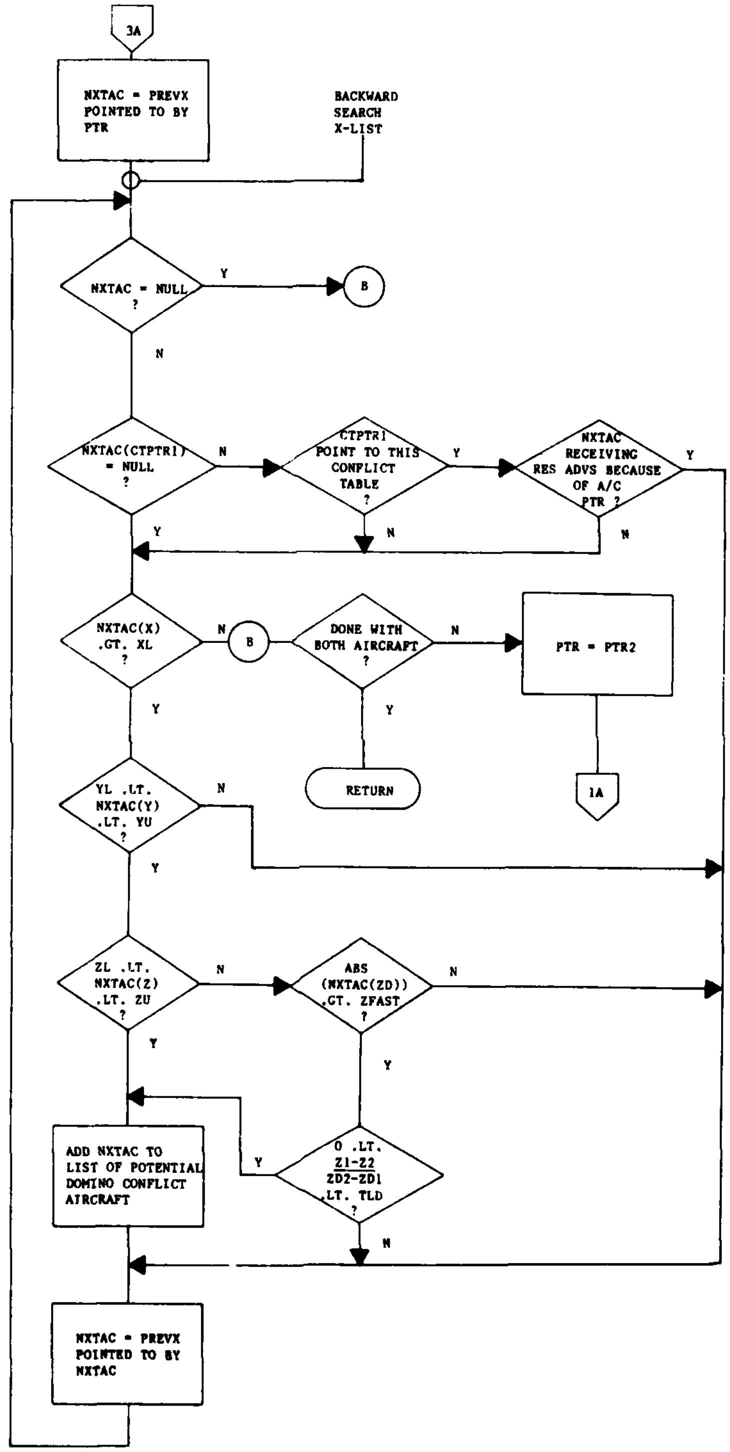


FIGURE 10-8
DOMINO COARSE SCREEN ROUTINE (Page 3 of 7)

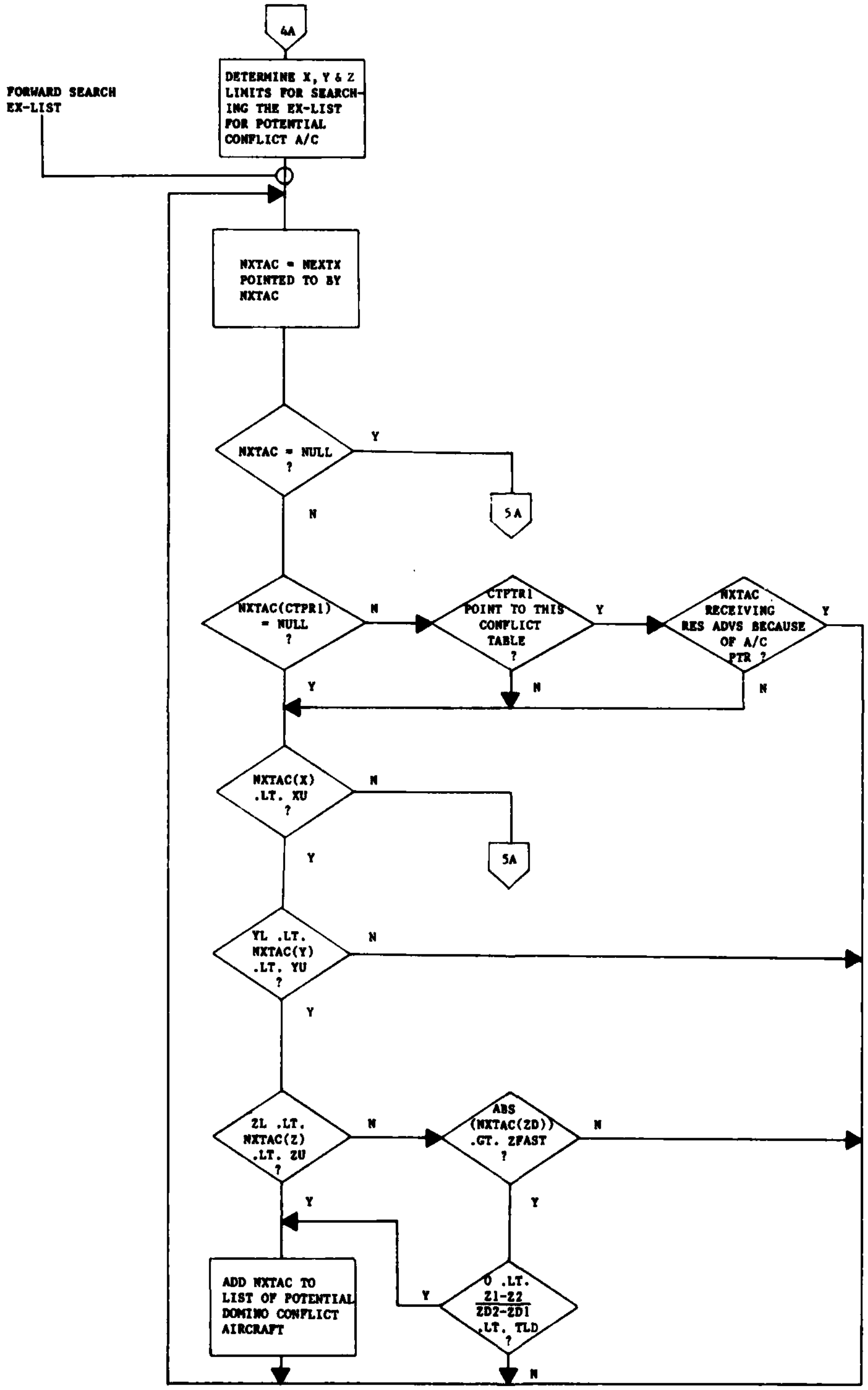


FIGURE 10-8
DOMINO COARSE SCREEN ROUTINE (Page 4 of 7)

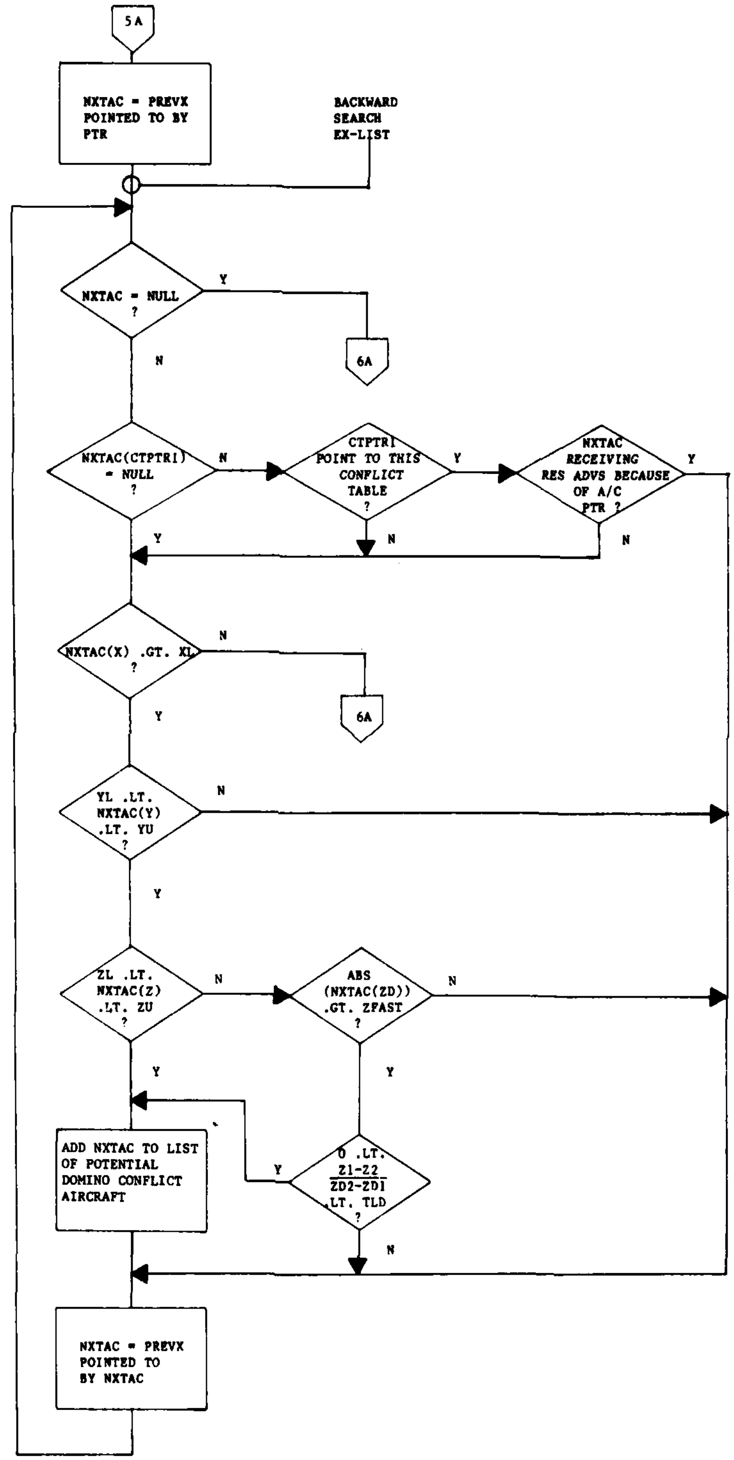


FIGURE 10-8
DOMINO COARSE SCREEN ROUTINE (Page 5 of 7)

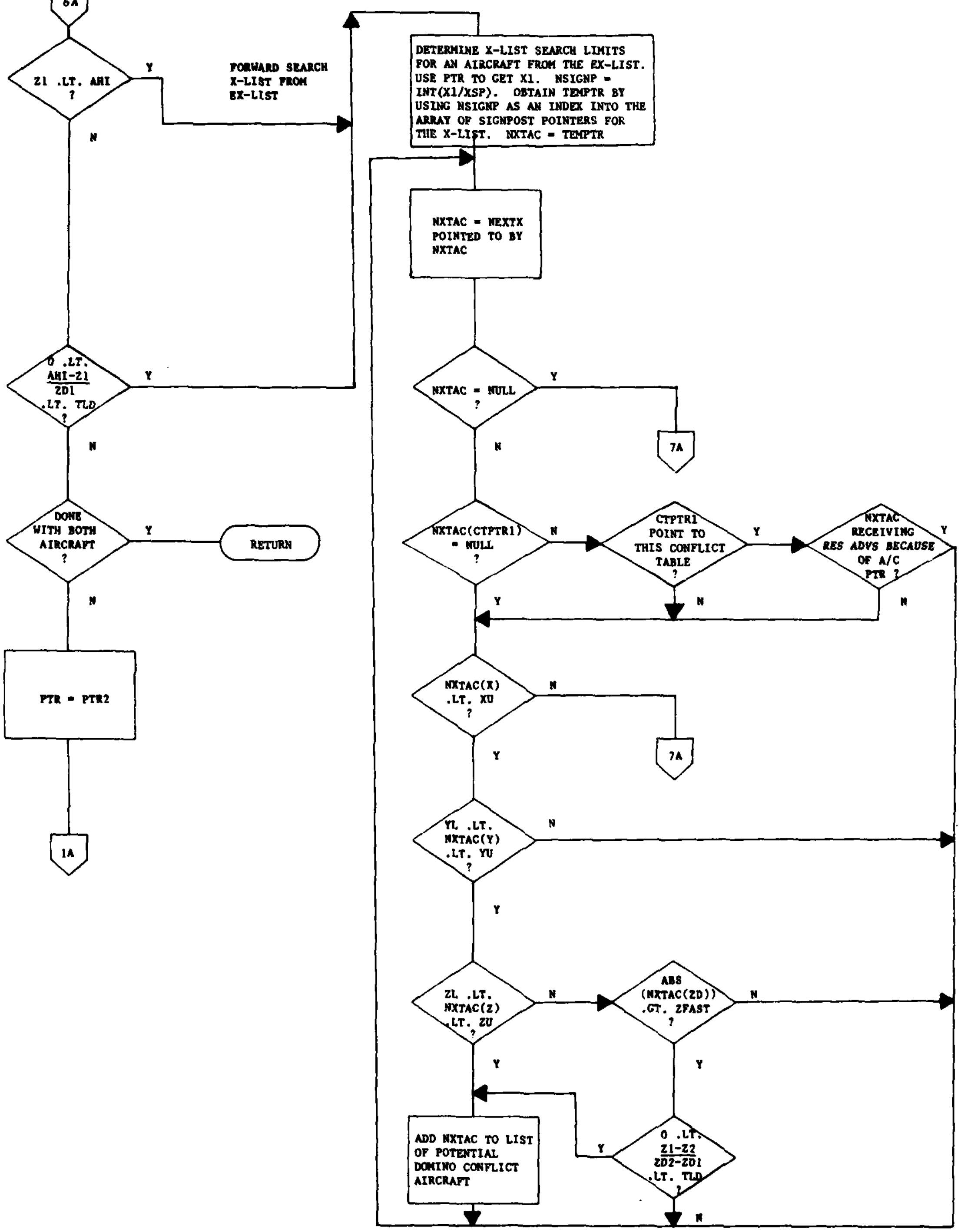


FIGURE 10-6
DOMINO COARSE SCREEN ROUTINE (Page 6 of 7)

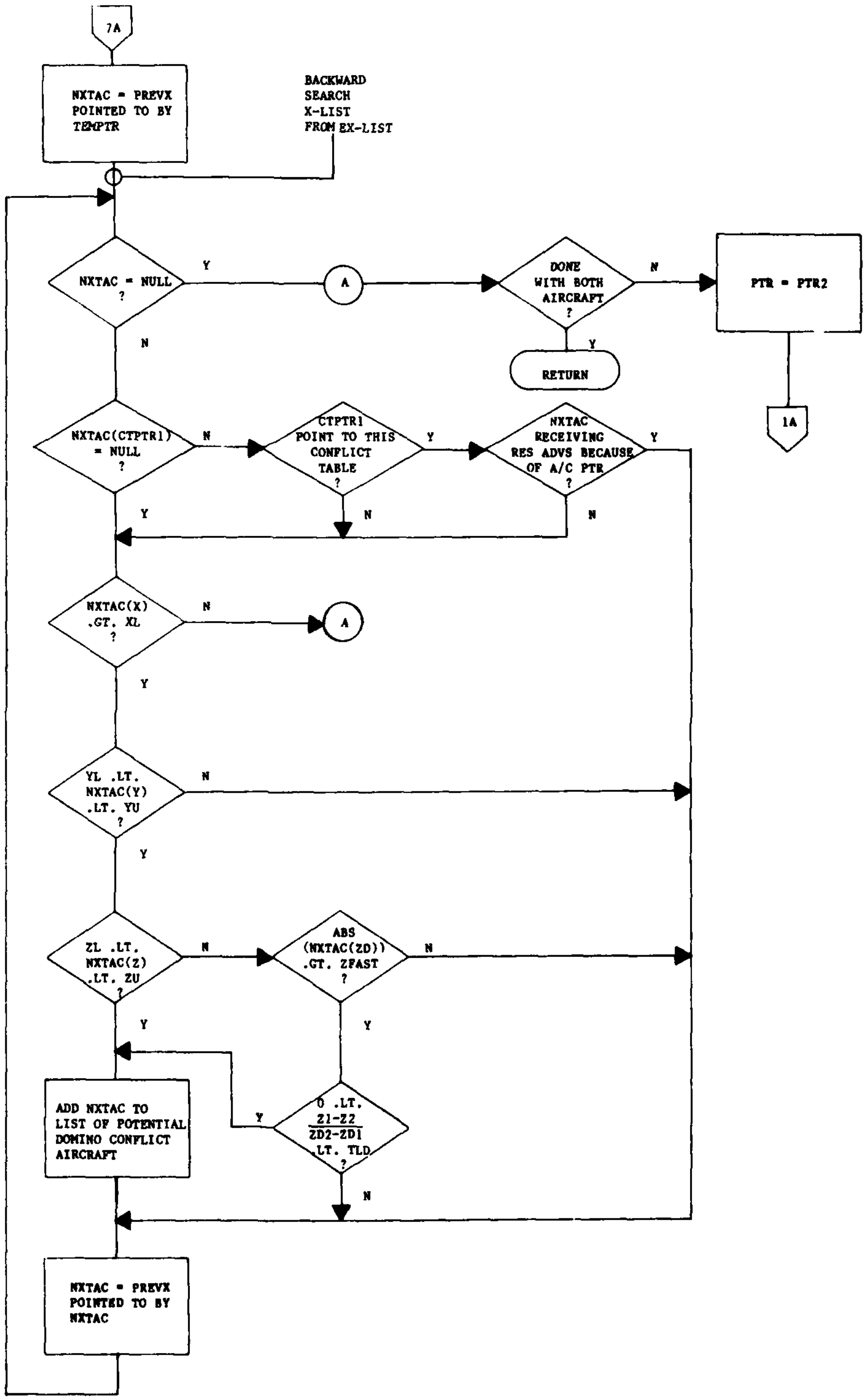


FIGURE 10-8
DOMINO COARSE SCREEN ROUTINE (Page 7 of 7)

The detection checks performed are only those checks that determine the need for resolution advisories. If the resolution advisory flag is set, then a domino conflict is declared. A domino conflict is indicated by setting the Potential Resolution Advisory flag to -1. Each one of the potential resolution advisories is checked for causing a domino conflict before going to the checks for the second aircraft. The checks performed on the second aircraft of the pair are exactly the same as those performed on the first aircraft.

10.3.1 Domino Coarse Screen Routine

The Domino Coarse Screen Routine creates a list of potential domino conflict aircraft for each maneuvered aircraft of the subject conflict pair. This is done by determining how far the maneuvered aircraft could fly in response to any of the resolution advisories, and adding to this distance, a distance that is the maximum immediate separation threshold distance used in search of conflicts requiring resolution advisories. To determine the area the maneuvered aircraft may cover, the potential resolution advisories must be known. The flags indicating these resolution advisories (see Table 10-10) are determined by searching through the linked list of resolution advisories. All resolution advisories with the Deliverable and Dimension Available Features set are included.

Figure 10-8 is the detailed flow chart of the Domino Coarse Screen Routine. Table 10-11 shows the equations for determining the search limits to be used by the Domino Coarse Screen Routine. The determination of the resolution advisory tau thresholds is shown in Table 10-12. The value of TLD used in the Domino Coarse Screen Routine is MANTM + DELAY + MAX (TCMDH,TCMDV).

The Domino Coarse Screen Routine performs a forward and backward search along the X-list or EX-list. The distance to be searched along the X-list is a function of the current speed and heading of the subject aircraft and the potential resolution advisories. The search limits are also a function of the subject aircraft being on the X-list or EX-list. If the subject aircraft is on the X-list, only the X-list is searched for potential conflict aircraft. If the subject aircraft is on the EX-list, the EX-list is searched and the X-list may be searched if the aircraft is close to the altitude limit of the X-list and projected to be within the altitude limits of the X-list within TLD seconds.

After determining which list the subject aircraft is on, the search limits along that list must be computed. To compute the

TABLE 10-11

DETERMINATION OF DOMINO COARSE SCREEN SEARCH LIMITS

Calculation of Search Limits

1st dimension of RAPP table - Resolution maneuver
2nd dimension of RAPP table - Projected positions and 4 lookahead times

X Search Limit Calculations

X(1)' = X(1,1) + XD(1,1) * TCMDH

If there is no positive horizontal resolution advisory for this aircraft in its conflict table entry:

X(2)' = X(1)' + XD(1,1) * (3*SCANTM + TCMDH)

If there is a positive horizontal resolution advisory for this aircraft in its conflict table entry:

X(2)' = X(1,2) + XD(1,2) * TCMDH
X(3)' = X(1,3) + XD(1,3) * TCMDH
X(4)' = X(1,4) + XD(1,4) * TCMDH

If LEFT, LTCL, or LTDS flag set:

X(5)' = X(2,1) + XD(2,1) * TCMDH
X(6)' = X(2,2) + XD(2,2) * TCMDH
X(7)' = X(2,3) + XD(2,3) * TCMDH
X(8)' = X(2,4) + XD(2,4) * TCMDH

If RGHT, RTCL, or RTDS flag set:

X(9)' = X(3,1) + XD(3,1) * TCMDH
X(10)' = X(3,2) + XD(3,2) * TCMDH
X(11)' = X(3,3) + XD(3,3) * TCMDH
X(12)' = X(3,4) + XD(3,4) * TCMDH

Use only computed X':

XU = Max (X(1)', X(2)',...,X(12)') + RMAX
XL = Min (X(1)', X(2)',...,X(12)') - RMAX

TABLE 10-11

DETERMINATION OF DOMINO COARSE SCREEN SEARCH LIMITS
(Concluded)

Use Table 10-12 to select parameters and:
If subject aircraft is controlled and on the X-list, do for:
    RMAX = 240 kts * (MANTM + DELAY + TCMDH) + RCMD2

If subject aircraft is controlled and on the EX-list, do for:
    RMAX = 600 kts * (MANTM + DELAY + TCMDH) + RCMD2

If subject aircraft is uncontrolled, do for:
    RMAX = 240 kts * (MANTM + DELAY + TCMDH) + RCMD2

Y Search Limit Calculations

The calculation of the Y direction search limits is exactly analagous to the calculation of the X direction search limits.

Altitude Search Limit Calculations

    Z(1)' = Z(1,1) + ZD(1,1) * (TCMDV + 3*SCANTM)

If CL, LTCL or RTCL flag set:
    Z(2)' = Z(2,1) + ZD(2,1) * (TCMDV + 3*SCANTM)

If DES, LTDS, or RTDS flag set:
    Z(3)' = Z(3,1) + ZD(3,1) * (TCMDV + 3*SCANTM)

If NCL, NDS or VSL flag set:
    Z(4)' = Z(4,1) + ZD(4,1) * (TCMDV + 3*SCANTM)

Use only computed Z':
    ZU = Max (Z(1)', Z(2)', Z(3)', Z(4)')+ ZMAX
    ZU = Min (Z(1)', Z(2)', Z(3)', Z(4)')+ ZMAX

If subject aircraft is controlled, do for:
    ZMAX = 1000 fpm * (MANTM + DELAY + TCMDV) + AF

If subject aircraft is uncontrolled, do for:
    ZMAX = 1000 fpm * (MANTM + DELAY + TCMDV) + AF

TABLE 10-12

RESOLUTION ADVISORY THRESHOLDS USED IN DOMINO LOGIC

AIRCRAFT PAIR*	TCMDH & TCMDV	RCMD2	AF
Controlled/Controlled			
1 a/c in area type 4	38 sec	0.75 nmi	750 ft
all others	30	0.75	750
Controlled/Uncontrolled			
1 a/c in area type 4	38 sec	1.0 nmi	750 ft
1 a/c in area type 3	30	1.0	750
all others	30	0.75	750
Uncontrolled/Uncontrolled			
all pairs	40 sec	0.0 nmi	750 ft

*In determining the detection thresholds for the Domino Coarse Screen Filter, use the value applicable to the subject aircraft that results in the maximum search area. If the subject aircraft is controlled, choose the values from controlled/uncontrolled thresholds that give the maximum Domino Coarse Screen search area.

For the Domino Detection logic, use the values applicable to the subject/object aircraft pair being checked for a domino conflict.

search limits, the resolution advisory tau threshold and immediate range parameters must be chosen. Table 10-12 is used to choose the resolution advisory tau threshold and immediate range parameters used in the Domino Coarse Screen Routine and the Domino Detection Routine.

Table 10-11 shows the calculations for determining the domino coarse screen search limits. If an aircraft is flying straight in the horizontal dimension, the search limits are linear projections of the aircraft's current speed in the X and Y directions. However, if the aircraft is turning or could potentially be turning, then adjustments must be made to the linear projection.

The module that performed the PSEP calculations also saved projected positions and velocities in response to potential resolution advisories in the RAPP table. To calculate the coarse screen limits, a TCMDH projection is made from each of the points along the response path in the RAPP table. There may be two sets of projections, if the resolution advisory time for controlled/uncontrolled encounters is different from the time for uncontrolled/uncontrolled or controlled/controlled encounters.

Once the minimum and maximum X and Y projected positions have been calculated, a buffer distance (RMAX) must be added to obtain the actual X-list (EX-list) search limits. The buffer is the distance that an aircraft going the maximum speed of an aircraft on the X-list (EX-list) can travel during the resolution advisory response projection interval (MANTM + DELAY) and the resolution advisory tau time (TCMDH), plus the immediate separation threshold (RCMD2). The maximum speeds are 240 kts for aircraft on the X-list and 600 kts for aircraft on the EX-list. A maximum vertical maneuver rate of 1000 ft/min is assumed for aircraft on the X-list and EX-list.

The altitude limits used in the Domino Coarse Screen Routine are computed similarly to the horizontal limits. That is, the maneuvered aircraft is projected from its current altitude using its current altitude rate for (MANTM + DELAY + TCMDV). The maneuvered aircraft is also modeled as responding to any computed maneuvers, positive, negative or VSL that appear in the aircraft's conflict table entry. Then the maximum and minimum altitudes are determined among each of the modeled paths and an altitude buffer (ZMAX) is added to obtain the altitude search limits used by the Domino Coarse Screen Routine.

After the search limits have been calculated, the Domino Coarse Screen Routine simply searches along the X-list (EX-list) looking for aircraft that are contained in the X, Y and Z search limits. Any aircraft within these bounds are added to the Potential Domino Conflict List for the subject aircraft (see Table 10-13).

Any aircraft within the search limits that are already in conflict and receiving a resolution advisory with the subject aircraft are not added to the Potential Domino Conflict List.

It is possible for an aircraft to be in more than one conflict on a scan. If this is the case, then it is possible to compute a list of potential domino conflict aircraft twice on the same scan for a particular aircraft. It is best to avoid this duplicate processing if possible. When a list of potential domino conflict aircraft is created for a subject aircraft, a pointer to the head of that list is saved in the pair record. Also in the pair record is a field of flags indicating which maneuvers were considered in the determination of the list. If an aircraft goes through master resolution and RER a second time on the same scan, then it is possible that the same Potential Domino Conflict List may be used. If the resolution advisories being considered for the second conflict are the same or a subset of the resolution advisories considered for the first conflict, then the same list of potential domino conflict aircraft may be used. The only exception is that the other aircraft in the current pair may be on the list of potential domino conflict aircraft. To use the same list of potential domino conflict aircraft, set the appropriate INDX parameter in this pair record to the same value as the INDX parameter for the subject aircraft in the previous pair record.

10.3.2 Domino Detection Routine

The remainder of the domino logic consists of performing the detection checks for conflicts requiring resolution advisories between the subject aircraft and each of the aircraft on the Potential Domino Conflict List. The detection checks are performed for each aircraft on the Potential Domino Conflict List or until a conflict is found, for each potential maneuver for the subject aircraft. The conflict detection parameters are determined according to the rules of Table 10-12.

To minimize the number of times the Domino Detection Routine is performed, a coarse detection check is made first to determine the need for performing the detailed conflict detection at each of the projected points. For each aircraft on the Potential

TABLE 10-13

POTENTIAL DOMINO CONFLICT LIST ENTRY

FIELD		CONTENT
INTRAC	-	Pointer to the state vector for this potential domino conflict aircraft.
CS1*, CS2	-	Flag for no horizontal advisory or negative horizontal advisory.
CVV1*, CVV2	-	Flag for no vertical advisory.
RGHT1*, RGHT2	-	Flag for right advisory.
LEFT1*, LEFT2	-	Flag for left advisory.
CLIMB1*, CLIMB2	-	Flag for climb advisory.
DESC1*, DESC2	-	Flag for descend advisory.
DCL1*, DCL2	-	Flag for don't climb advisory.
DDES1*, DDES2	-	Flag for don't descend advisory.
VSL1*, VSL2	-	Flag for VSL advisory.
XPRJ1, YPRJ1, XPRJ2, YPRJ2, XPRJ3, YPRJ3, XPRJ4, YPRJ4	-	Horizontal projected positions for this aircraft.

TABLE 10-13

POTENTIAL DOMINO CONFLICT LIST ENTRY
(Concluded)

FIELD		CONTENT
XDPRJ1, YDPRJ1, XDPRJ2, YDPRJ2, XDPRJ3, YDPRJ3, XDPRJ4, YDPRJ4	-	Horizontal projected velocities for this aircraft.
ZPRJ1, ZPRJ2, ZPRJ3, ZPRJ4	-	Vertical projected positions for this aircraft.
ZDPRJ	-	Vertical projected velocity for this aircraft.
NXTINTR1, NXTINTR2	-	Pointer to the next aircraft in the list of potential domino conflict aircraft.

---

* 0 - This advisory for the subject aircraft has not been checked for causing a domino conflict with this aircraft.

1 - This advisory to the subject aircraft causes a domino conflict with this aircraft.

2 - This advisory for the subject aircraft has been checked and it does not cause a domino conflict with this aircraft.

Domino Conflict List, the values in Table 10-14 are calculated and the tests in Figure 10-9 are performed. First, it is determined if the two aircraft will be in conflict in the vertical dimension at any time during the projected maneuver interval. If a conflict in the vertical dimension is not possible during the maneuver interval, then the detection checks do not have to be performed for this potential domino conflict aircraft. Otherwise, a coarse check in the horizontal dimension is performed. This check bypasses the detection checks if the aircraft are diverging and presently separated by more than the immediate range threshold for a conflict. However, if the potential domino conflict aircraft is receiving a positive horizontal resolution advisory, or the potential resolution maneuver to the subject aircraft is a positive horizontal resolution advisory, then the horizontal coarse detection check is not performed.

The detection checks performed to determine a conflict are just the resolution advisory detection checks of Section 7.1.1.

The Domino Coarse Detection Routine (Figure 10-9) should not be confused with the Domino Coarse Screen Routine. The Domino Coarse Screen Routine generates a list of aircraft which are in the vicinity of the pair of aircraft in conflict. The coarse detection checks are a way to reduce the detection computations needed to determine conflicts between aircraft on the Potential Domino Conflict List and a subject aircraft from the conflict pair.

The checks for determining the need for resolution advisories requires the computation of tau values and immediate range values. The Domino Detection Routine must compute these values at four points along the projected path of each potential domino conflict aircraft paired with an aircraft from the subject pair. In addition, it is possible to repeat the same calculations twice between the same two aircraft. For example, if a maneuvered aircraft may receive either a "turn left" or "turn right" advisory, then the domino logic would compute the same vertical taus and separations against a particular aircraft when checking each horizontal advisory for causing a conflict. The number of computations could be reduced by remembering the outcome of the linear projection checks between the two aircraft. The data structure for the potential domino conflict aircraft list contains fields to remember the outcome of the linear projection checks.

TABLE 10-14

DOMINO COARSE DETECTION ROUTINE CALCULATIONS

Z1, ZD1	-	Altitute and altitude velocity of subject aircraft at projection time (TEN + 3*SCANTM) from the RAPP table.
Z2, ZD2	-	The (TEN + 3*SCANTM) projected altitude and altitude velocity of the aircraft from the potential domino conflict list.
X1, Y1 XD1, YD1	-	Horizontal position and velocity components of subject aircraft at projection time (TEN + 3*SCANTM) from the RAPP table.
X2, Y2 XD2, YD2	-	The (TEN + 3*SCANTM) projected horizontal position and velocity components of the aircraft from the potential domino conflict list.

VRZ
TV
ALT
DOT ---------- Equations described in Figure 7-2
DSQ
TH
RANGE2

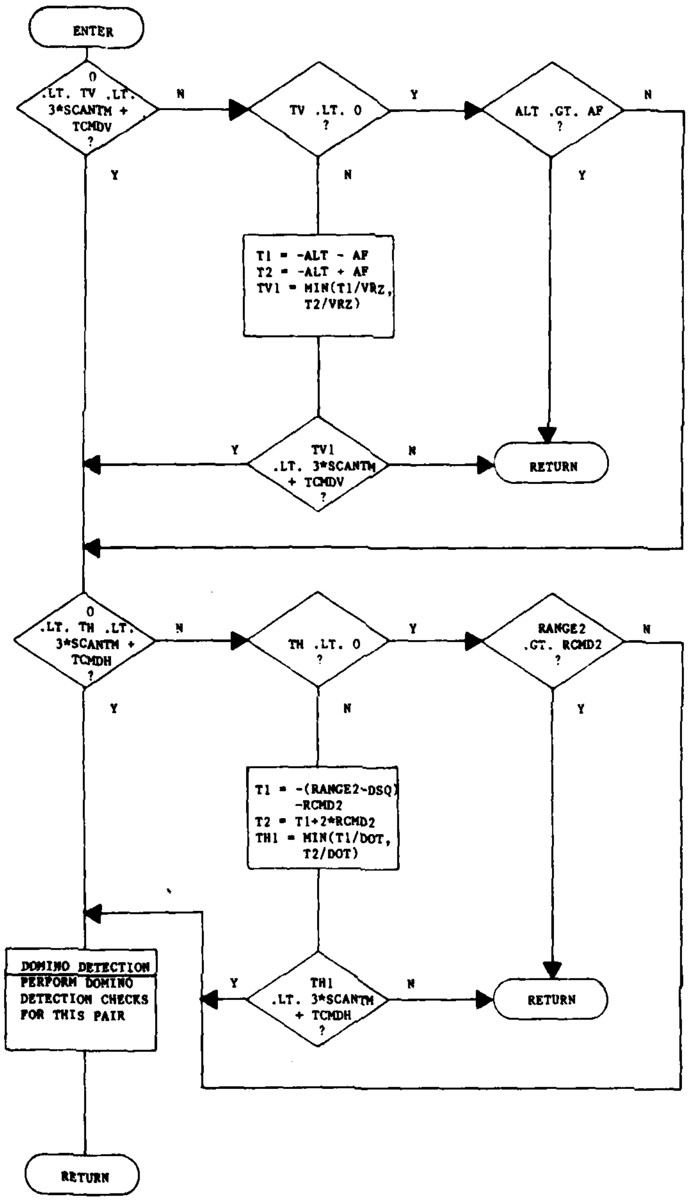


FIGURE 10-9
DOMINO COARSE DETECTION ROUTINE

Another savings of computation time can be achieved by performing the linear detection checks at the earliest time of data in the RAPP table (TEN + 3*SCANTM) and increasing the tau threshold to include all of the projection time of the RAPP table (TEN + 6*SCANTM). Also, the immediate range test may be approximated by computing the range at time (TEN + 3*SCANTM) and then comparing this value to the threshold value and determining if the aircraft are diverging or converging. Table 10-14 shows the computations necessary to perform the coarse detection checks.

The altitude velocity used for the aircraft from the Potential Domino Conflict List is the aircraft's current altitude velocity unless that aircraft is in a conflict and has a resolution advisory. If a vertical advisory appears in a conflict table entry for that aircraft, then a nominal vertical velocity is used if the sense of the advisory differs from the aircraft's current velocity. For example, if an aircraft has a "don't climb" advisory and a positive vertical velocity, then use a nominal level (zero) vertical velocity.

If an aircraft on the Potential Domino Conflict List is receiving a positive horizontal resolution advisory, then model a response path for that aircraft in order to perform the horizontal portion of the conflict detection checks. The projection will be at the aircrafts current speed and heading if it is receiving a negative horizontal resolution advisory or no horizontal resolution advisory.

11. CONTROLLER ALERT PROCESSING

Controller alert processing generates a Controller Alert Message which has three types of data generated at different times. Generation of the first two types of data is described below. Generation of the third type of data is one of the functions of the Data Link Message Construction Task, discussed in Section 14.

1. Conflict Resolution Data - Alerts controller to a potential conflict and provides ATARS resolution advisories.

2. Resolution Notification Data - Informs the controller that the aircraft have received resolution advisories.

3. Avoidance Alert Data - Informs the controller that a controlled aircraft has received a terrain, obstacle, or restricted airspace alert.

A Controller Alert Message with conflict resolution data contains the initial maneuvers selected for the aircraft pair which is displayed to the controller but not displayed to the aircraft. A Controller Alert Message with resolution notification data contains resolution advisories displayed to the controller after receipt by the aircraft. Normally, the first message is generated when the ICAFLG is set or a controller alert has been requested for 3 out of 5 of the previous ATARS processing scans and the second message is displayed when ATARS receives confirmation that the aircraft have accepted the resolution advisories.

Within one Controller Alert Message for a pair, the delivery status field (DEL) is set for the pair. When a pair that is controlled/uncontrolled is initially recognized, DEL is set to 001 and ATARS resolution data is computed for the uncontrolled aircraft. No resolution data in computed for the controlled aircraft. After confirmation that the resolution advisory has been accepted by the uncontrolled aircraft, DEL is set to 011 for both aircraft even though no resolution advisory has been computed or delivered for the controlled aircraft. After confirmation is received that a resolution advisory has been accepted by the controlled aircraft, the Controller Alert Message will display the accepted resolution advisory.

The Controller Alert Message applies to a pair of aircraft. A separate message is generated for each pair. If one aircraft of a pair is involved in a multiple aircraft conflict, several messages pertaining to a single aircraft will be delivered.

Three data structures are used for controller alert processing.

1. Controller Alert List Buffer - A temporary list passed in, read, and cleared in controller alert processing. Each entry on the list contains the ID's of the aircraft, ICAFLG, and the sector ID of the pair giving rise to the controller alert.

2. Controller Alert List - A permanent list created from the Controller Alert List Buffer during controller alert processing. This list contains the ID's of the aircraft, the time of the most recent controller alert request, the horizontal and vertical maneuvers selected for the aircraft pair, and the sector ID's of the aircraft. Table 11-1 lists the logical content of the Controller Alert List.

3. Controller Alert Message - A temporary data structure created each time a new message is sent to the controller. Table 11-2 lists the logical content of a Controller Alert Message. External transmission and screen formatting is handled outside the ATARS software.

Controller alert processing is conceptually divided into three functions. The first function processes aircraft pairs and generates data used for the controller alert. The second function reads data from the aircraft CIR and generates data used for the controller notice. The third function processes the data and sends the message to the ATC facility. In practice, however, each function is not neatly compartmentalized into its own routine due to the timing constraints imposed by Sector Oriented Task Sequencing (Figure 3-1). Figures 11-1, 11-2, and 11-3 provide the detailed flow charts of controller alert processing.

As shown in these flow charts, the controller alert processing functions are divided by task and routine as described below:

1. Controller Alert (Conflict Resolution Data) Task - Processes aircraft pairs on the Controller Alert List Buffer and initalizes or updates entries on the Controller Alert List. After the pair bypasses or completes a timing delay, it goes to alert status and conflict resolution data is generated for a Controller Alert Message (function one and three).

2. Update Controller Alert List Routine - Processes CIR data to update the Controller Alert List. After pair records are updated from downlinked CIR data, they are

TABLE 11-1

LOGICAL CONTENT OF CONTROLLER ALERT LIST

FIELD		CONTENT
ACID1	-	Identifier of aircraft 1 of the pair in conflict.
ACID2	-	Identifier of aircraft 2 of the pair in conflict.
ALTIM1	-	Most recent time of a controller alert request for aircraft 1.
ALTIM2	-	Most recent time of a controller alert request for aircraft 2.
CHMAN1, CVMAN1	-	Horizontal and vertical maneuvers for aircraft 1.
CHMAN2, CVMAN2	-	Horizontal and vertical maneuvers for aircraft 2.
WINSTR	-	Bit string variable used for timing the update or deletion of the pair from the Controller Alert List.
STATUS	-	Variable used for maintaining the status of a pair on the Controller Alert List. The pair status may be initial, alert, or final.
CALSID	-	Variable used for maintaining the current sector ID (position) of the aircraft pair.

TABLE 11-2

LOGICAL CONTENT OF CONTROLLER ALERT MESSAGE*

FIELD		CONTENT
ACID1	-	Identifier of aircraft 1 of the pair in conflict.
ACID2	-	Identifier of aircraft 2 of the pair in conflict.
CS1	-	Control status (controlled/uncontrolled) and the equipment of aircraft 1 as known to the ATARS system.
CS2	-	Control status (controlled/uncontrolled) and the equipment of aircraft 2 as known to the ATARS system.
HMAN1,VMAN1	-	Horizontal/vertical maneuvers for aircraft 1.
HMAN2,VMAN2	-	Horizontal/vertical maneuvers for aircraft 2.
DEL1	-	Delivery status of maneuvers for aircraft 1.
DEL2	-	Delivery status of maneuvers for aircraft 2.
V1	-	Indicates possible need for controller voice communications to aircraft 1.
V2	-	Indicates possible need for controller voice communications to aircraft 2.
AMTYP	-	Alert message type indicating a controller alert or that an alert has been sent to aircraft 1 (terrain, obstacle, or restricted airspace alert).

* See Reference 8.

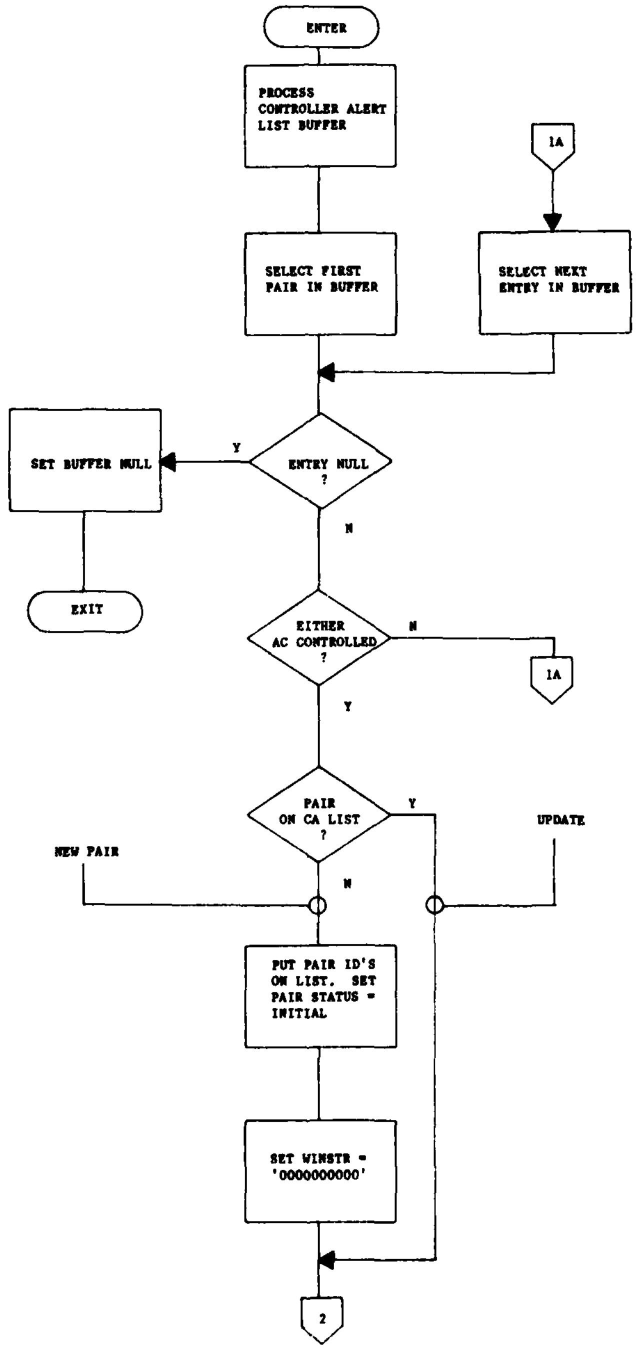


FIGURE 11-1
CONTROLLER ALERT (CONFLICT RESOLUTION DATA) TASK (Page 1 of 3)

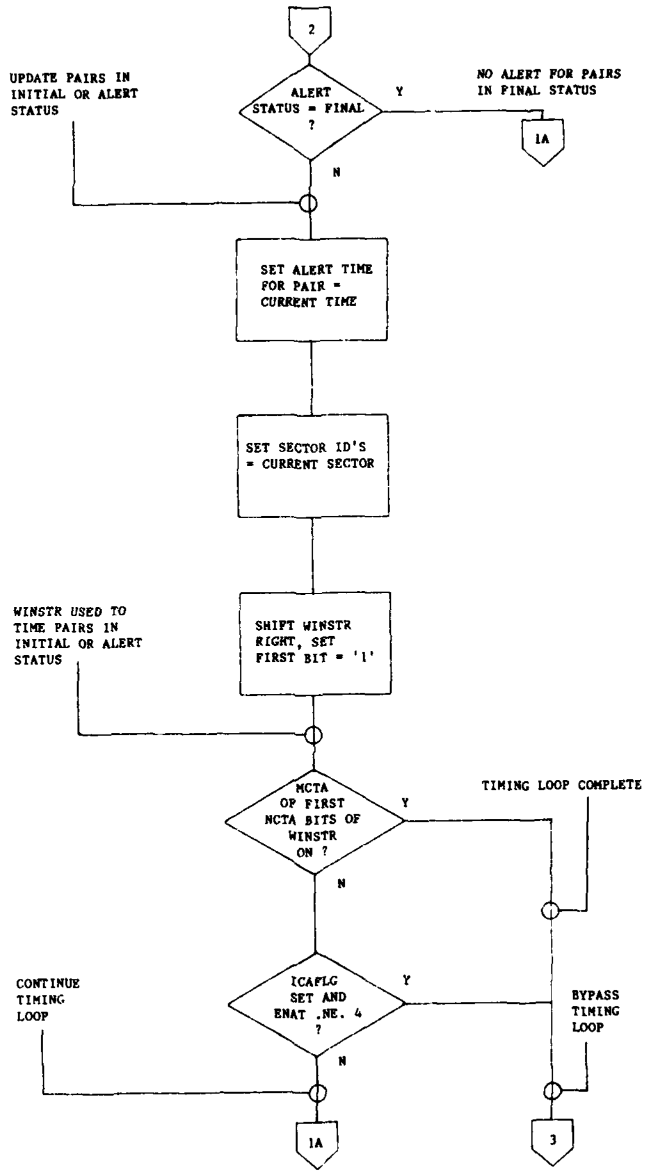


FIGURE 11-1
CONTROLLER ALERT (CONFLICT RESOLUTION DATA) TASK (Page 2 of 3)

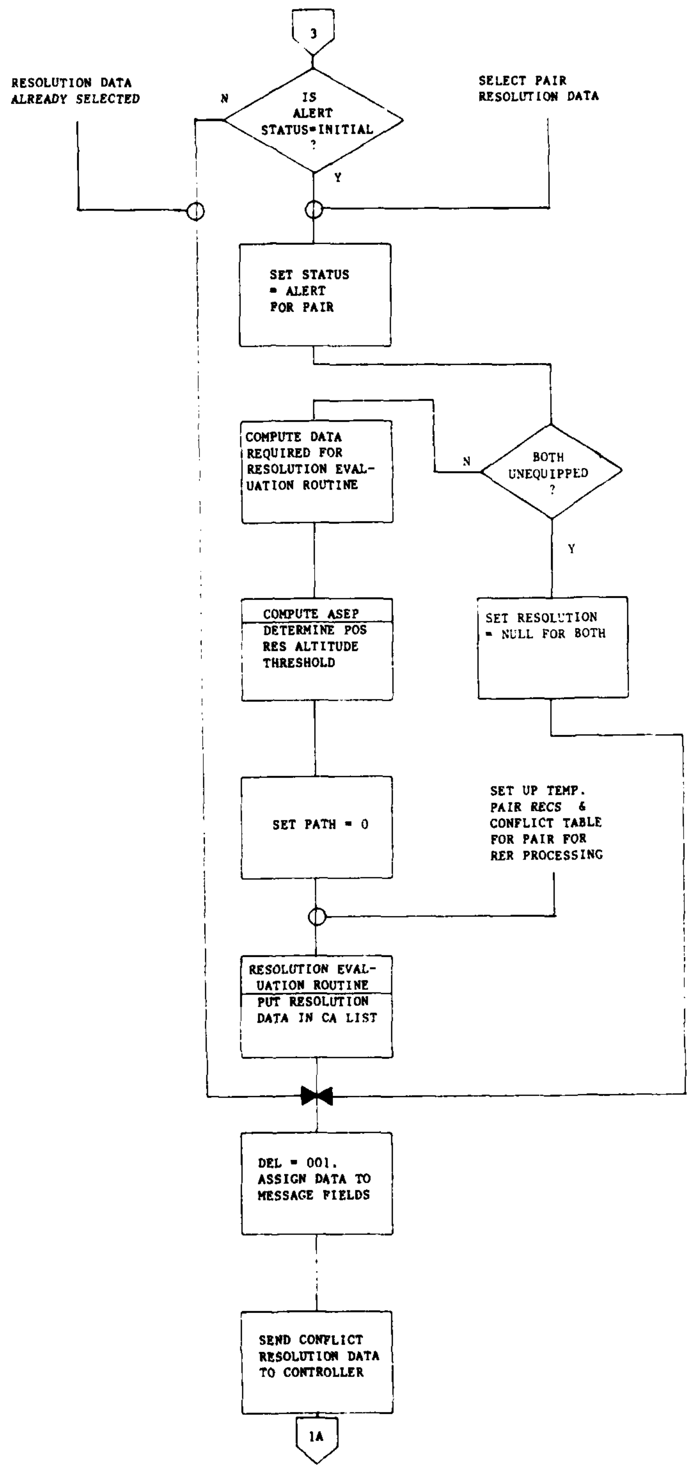


FIGURE 11-1
CONTROLLER ALERT (CONFLICT RESOLUTION DATA) TASK (Page 3 of 3)

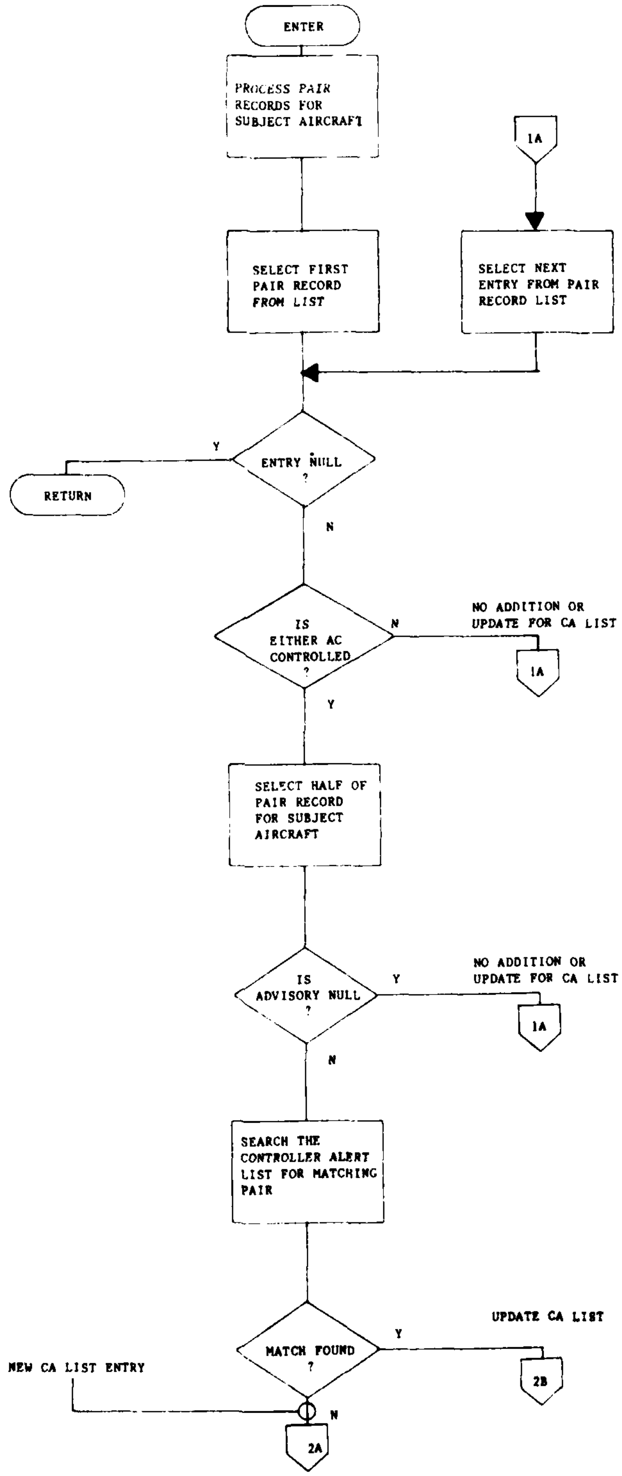


FIGURE 11-2
UPDATE CONTROLLER ALERT LIST ROUTINE (Page 1 of 2)

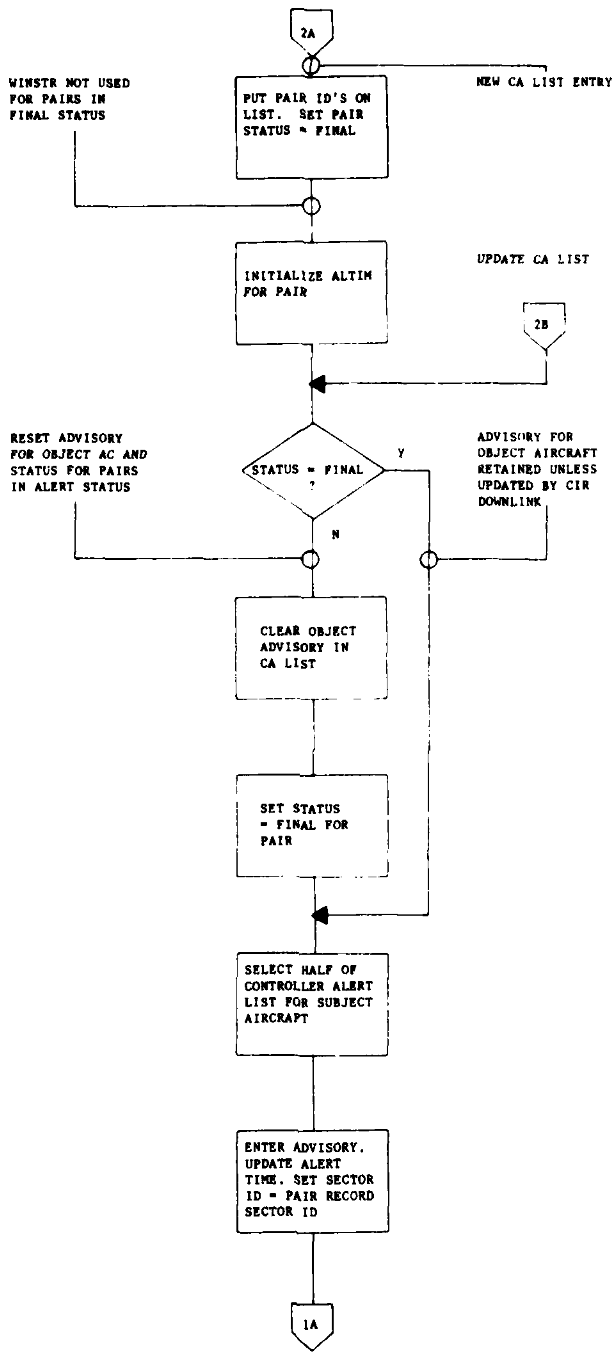


FIGURE 11-2
UPDATE CONTROLLER ALERT LIST ROUTINE (Page 2 of 2)

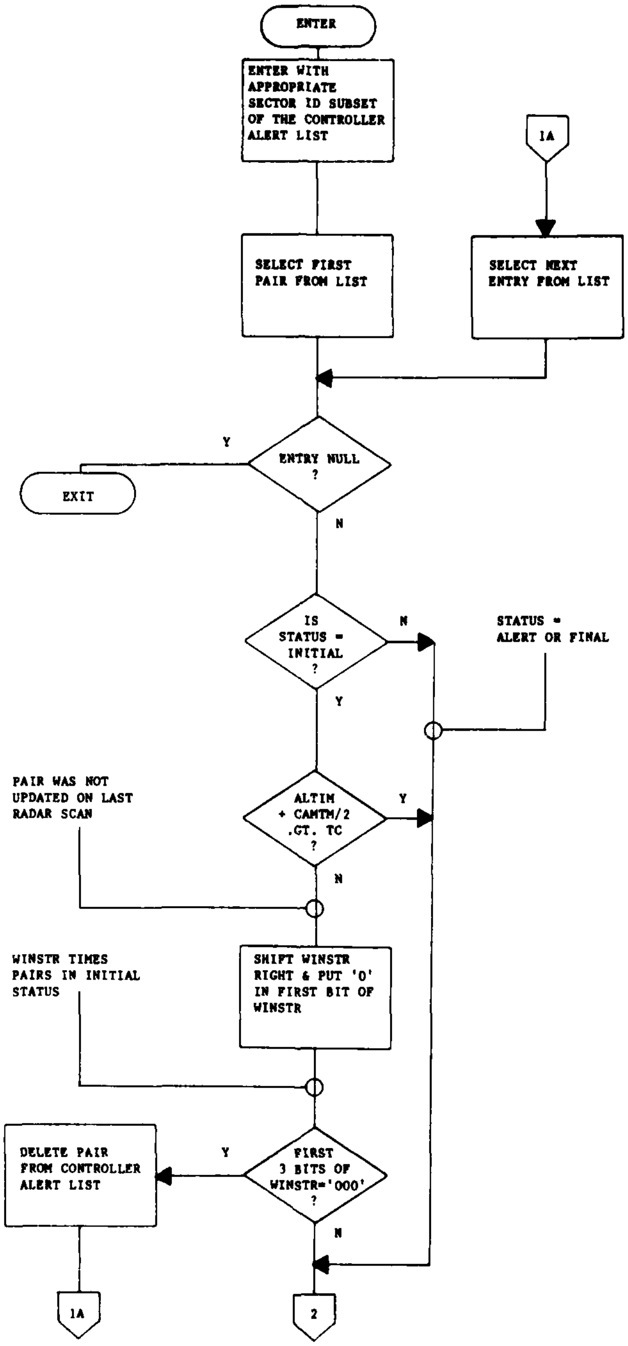


FIGURE 11-3
CONTROLLER ALERT (RESOLUTION NOTIFICATION) TASK (Page 1 of 3)

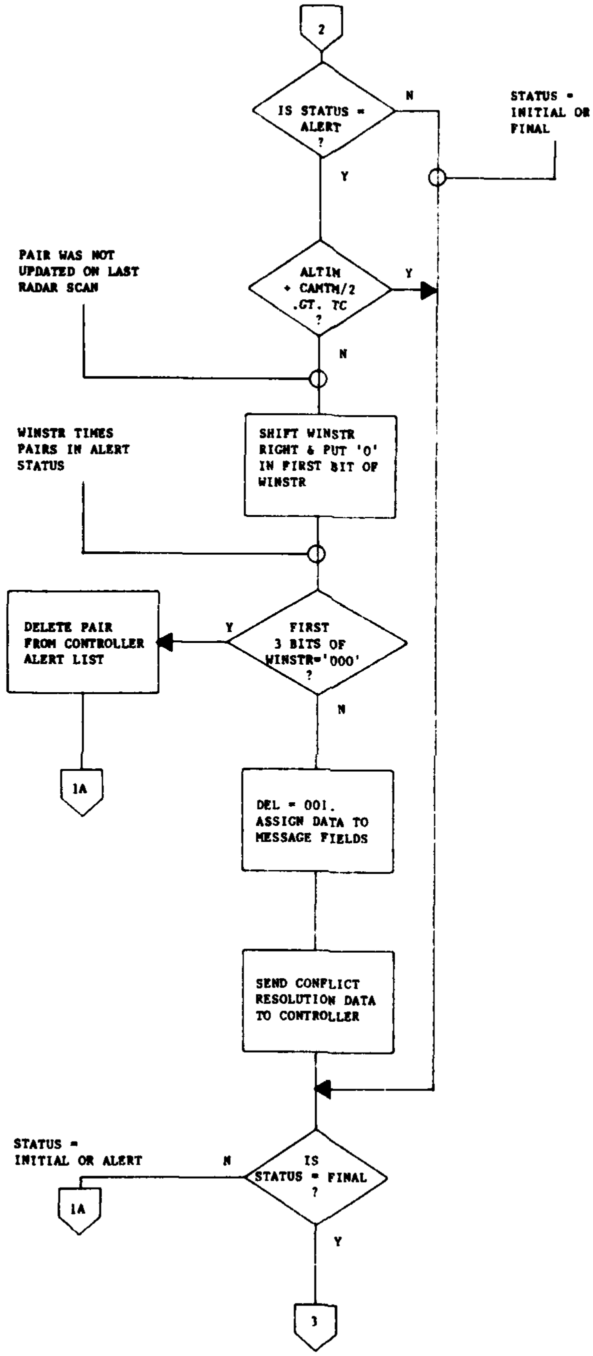


FIGURE 11-3
CONTROLLER ALERT (RESOLUTION NOTIFICATION) TASK (Page 2 of 3)

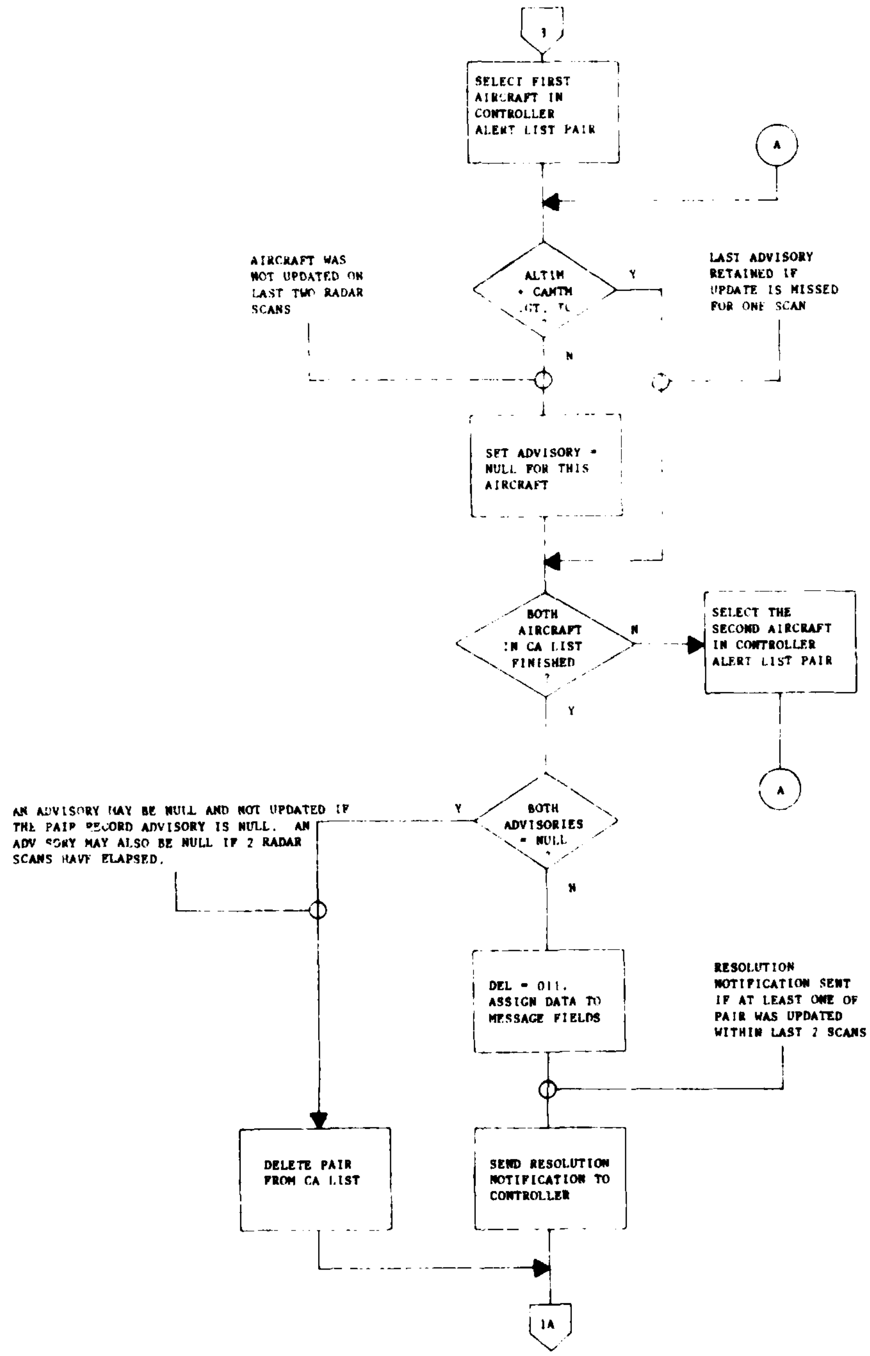


FIGURE 11-3
CONTROLLER ALERT (RESOLUTION NOTIFICATION) TASK (Page 3 of 3)

passed to this routine. Resolution data from the pair records is used to initialize or update entries on the Controller Alert List, and the pair status becomes final (function two).

3. Controller Alert (Resolution Notification) Task - Processes all pairs on the Controller Alert List for the appropriate sector. It deletes pairs that aren't updated after both aircraft have missed update for two scans. It sends conflict resolution data for pairs in alert status and sends resolution notices for pairs in final status (functions one and three).

12. MULTI-SITE RESOLUTION PROCESSING

This section describes intersite ATARS communication and the protocol involved. Communication among sites is required when aircraft are in conflict in regions serviced by more than one ATARS. The protocol involves the messages exchanged and house-keeping actions required to maintain an accurate data base.

When aircraft are in regions covered by adjacent sites, these sites coordinate to assure continuity and non-duplication of resolution service. Two means of coordination are provided in this design. Conflict tables are exhanged using ground communication lines, where a network connection exists between two sites. This is described in Section 12.1. Elsewhere, the coordination is performed through the aircraft transponders using the Conflict Indicator Register (CIR) required for all ATARS-equipped aircraft. This register also enables coordination between ATARS and BCAS. This coordination is described in Section 12.2. See Table 5-2 for a description of the information contained in the CIR.

The ATARS site responsible for a conflict is indicated by the ATSID variable in the conflict table pair record. A detailed description of this variable is given in Table 12-1.

Section 12.3 describes special communications between connected sites which are required only when a site fails to receive CIR data for an aircraft in the CIR Buffer. Section 12.4 describes the procedure to delete an aircraft state vector from storage. Section 12.5 describes management tasks for conflict tables involved in a seam between sites.

12.1 Conflict Table Exchange Using Ground Lines

The primary means of multi-site coordination uses ground lines, wherever these are installed. This method provides ATARS a complete and current copy of the neighboring site's conflict tables so that seam conflicts may be recognized and correctly resolved.

Whenever the Seam Pair Task (Section 7.2) recognizes a conflict containing an aircraft in a seam, it places the pair on the Delayed Resolution List. The Request and Process Remote Conflict Tables Task (Figure 12-1) initiates a message through the DABS ground line network to all neighboring sites covering any part of the conflict. The request (see Table 12-2) identifies the pair of aircraft that own-site intends to resolve. This task then becomes dormant until a reply is received. The sector

TABLE 12-1

CONTENT OF ATSID VARIABLE IN PAIR RECORD

FIELD	NO. BITS	MEANING
ID	4	Identification of ATARS site responsible for this pair.
Handoff	1	Pair is in handoff status when set. ID field above designates site previously responsible.
External	1	Indicates other ATARS site with same ID as own site. Only used in backup mode when center zone is adjacent to such a site.

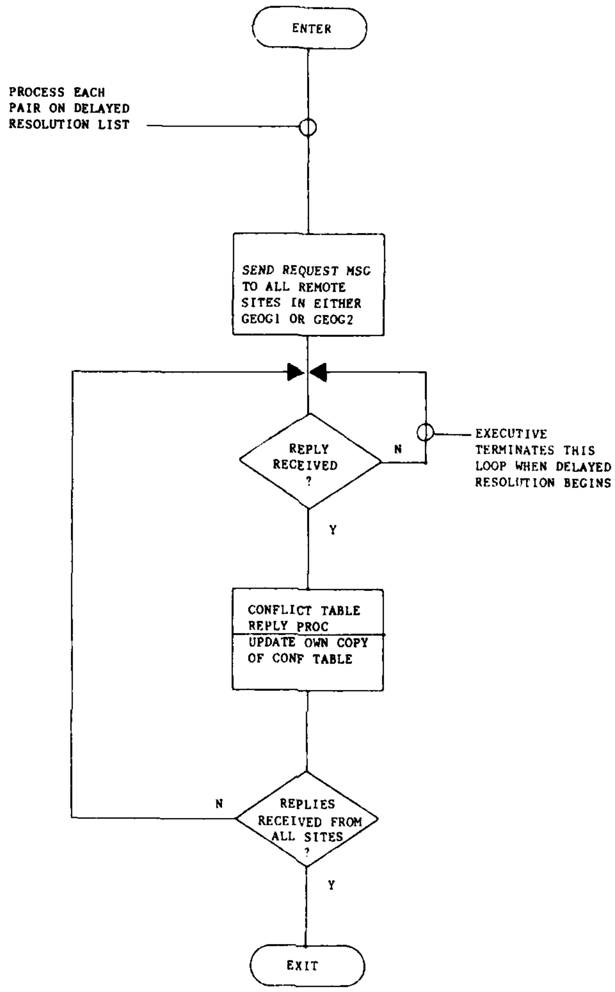


FIGURE 12-1
REQUEST AND PROCESS REMOTE CONFLICT TABLES TASK

TABLE 12-2

FORMAT OF CONFLICT TABLE EXCHANGE MESSAGES
(USING GROUND COMMUNICATION LINES)

1. Request (may be sent to several sites with NID changed as appropriate)

FIELD	MEANING
OWNID	Own ATARS ID
NID	Neighboring site ATARS ID
AC1TYP	Aircraft 1 Type (DABS or ATCRBS)
AC1ID	DABS Address; or position data and file number if ATCRBS
AC2TYP	Aircraft 2 Type
AC2ID	Aircraft ID same as AC1ID
REPLY (1 bit)	Do/Don't Send Reply
DEL (1 bit)	Delete Pair Record

2. Reply

FIELD	MEANING
OWNID	Requesting site ATARS ID
NID	Replying site ATARS ID
AC1TYP, AC2TYP,	Same as request
AC1ID, AC2ID	Same as request
NTABL	Number of conflict tables (0, 1, or 2)
CT1	First conflict table if any
CT2	Second conflict table if any

processing executive has the responsibility to terminate the task prematurely when it is time to begin the Master Resolution (Delayed) Task. The neighboring site returns a message to the requesting site containing zero, one, or two conflict tables (see Table 12-2). Two tables would be returned if the site had the two subject aircraft in unconnected conflicts. This routine merges these conflict tables, so that requests on subsequent scans should always receive one conflict table in the reply.

When the requesting site receives each reply from a neighboring site, it executes the Conflict Table Reply Processing Routine (Figure 12-2). This routine updates, adds or deletes pair records whose ATSID is or was set to the neighboring site's ID. This routine must be executed even if the reply contains no conflict table, as pair records may exist in own-site's copy of the conflict table. However, if no ground line connection exists, or if the reply is not received by the time the Sector Processing Executive determines processing must continue, this routine is not executed. In this case the latest CIR processing update (Section 5.3) gives information on the neighboring sites' actions.

When a site receives a request for conflict tables, that site executes the Incoming Seam Pair Request Processing and Reply Task (Figure 12-3). This task generates the reply message and sets ATSID in the pair record to the requesting site's ID, unless the pair is already being resolved by own-site.

Any ATCRBS aircraft which appears in an exchanged conflict table must be subjected to a correlation procedure by the receiving site when that ATCRBS aircraft first appears. It is necessary to perform this correlation procedure to prevent two adjacent sites from creating separate conflict table entries for the same aircraft.

The site which originates the conflict table with the ATCRBS aircraft will identify that aircraft with a unique ID on the first and all subsequent exchanges. The receiving sites need perform the correlation only once. Thereafter, a cross-reference will link that ID to the local state vector. The ID selected for this purpose must be one that cannot be duplicated by another remote site. For this reason, it is suggested that an ID be constructed by a concatenation of the local CTS slot number with the ID of the local site.

This cross-reference will contain entries for all ATCRBS aircraft within the local ATARS mask which the local ATARS function currently has in conflict tables that are being exchanged. It

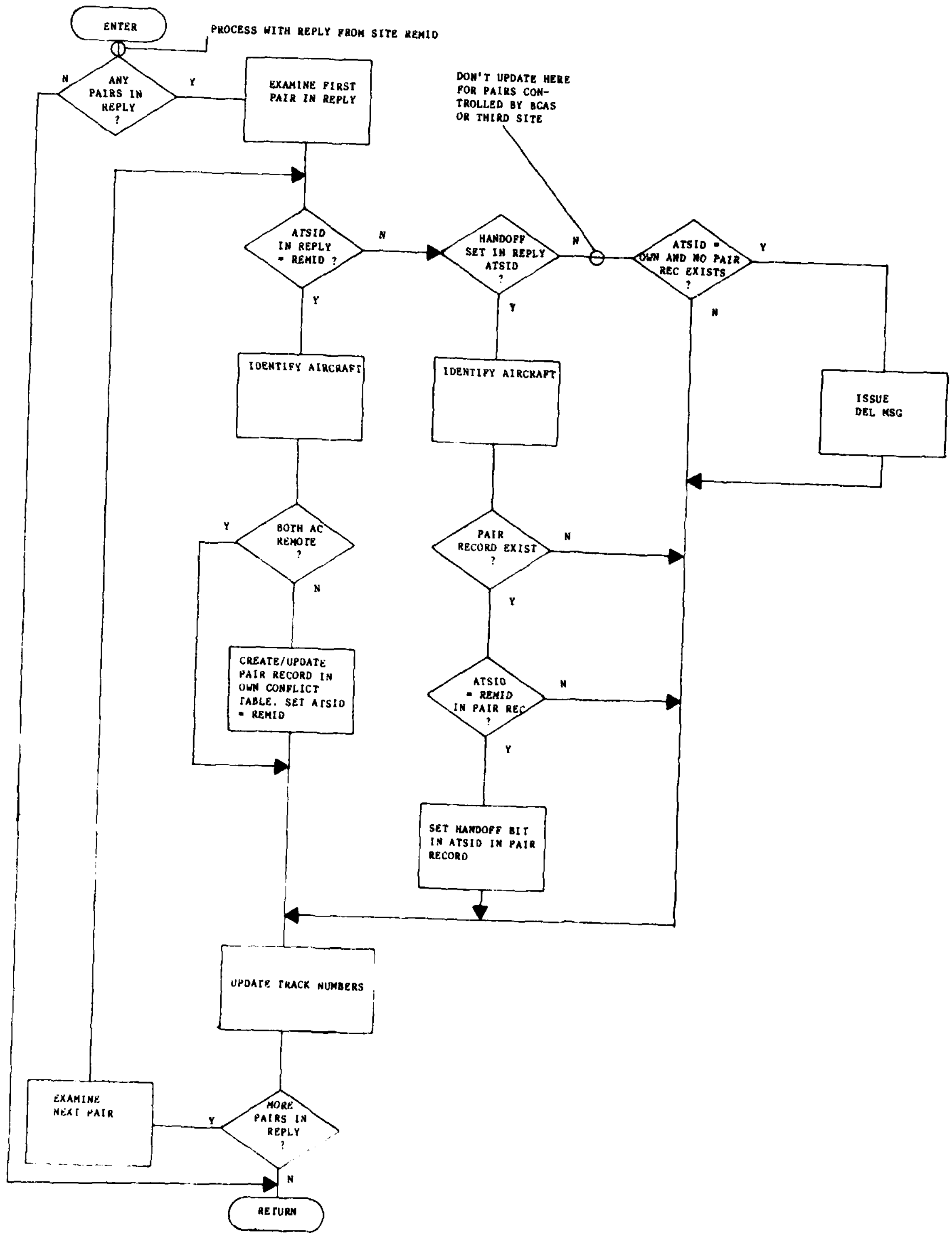


FIGURE 12-2
CONFLICT TABLE REPLY PROCESSING ROUTINE

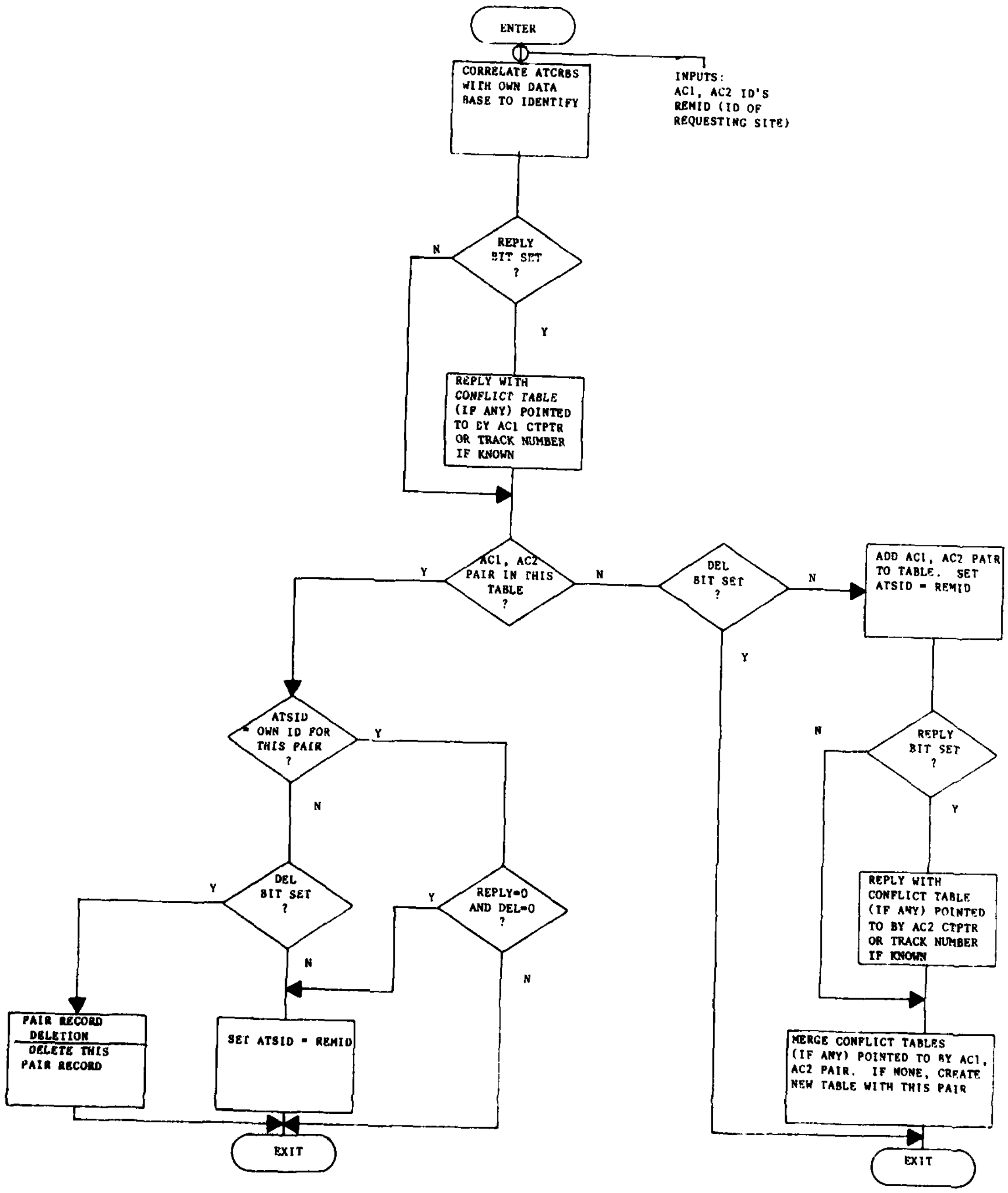


FIGURE 12-3
INCOMING SEAM PAIR REQUEST PROCESSING AND REPLY TASK

is identified as CREFX and is entirely unrelated to the CREFA cross-reference used in report processing. Each entry in CREFX consists of an ATCRBS ID (created by either a local or remote ATARS) and a pointer to the state vector of this aircraft in the local CTS. For ATCRBS aircraft, the pointer in the state vector designated ATCREF will be used as a return pointer to this entry in CREFX. Only those ATCRBS aircraft which are in seam conflict tables will have an entry in CREFX and have a non-null value for ATCREF.

ID's of ATCRBS aircraft may be added to CREFX in two ways. First, when a conflict table is received from a remote site with an ATCRBS ID which is not already in CREFX, that ID is added. Second, when performing CIR processing and an ATCRBS aircraft which is not in CREFX appears in a downlinked conflict table, a new ID is created and added.

The ATCRBS correlation procedure described in Section 5.3 is used. It consists of a proximity test plus ATCRBS code check. An ATCRBS report is always transmitted with the conflict table when an ATCRBS aircraft is in the conflict table. This report consists only of the current predicted range, azimuth, and altitude coordinates and the ATCRBS code. In the ATCRBS correlation, the remote range and azimuth are converted to local coordinates. The correlation procedure consists of using the X-list in much the same way as in coarse screening. The proper location of the ATCRBS report in the X-list is found. A search along the X-list in both directions to X limits is made. All aircraft encountered are tested against Y and Z limits and against the ATCRBS code. The correlation procedure is successful if one and only one ATCRBS aircraft is found satisfying the requirements.

Correlation should be attempted every cycle until a successful correlation occurs. Hence, the failure to correlate on the first appearance of a new ATCRBS aircraft is not fatal. An entry in REMA is created and used until a successful correlation occurs.

Two other new data structures, besides CREFX, are used to provide cross-referencing during the processing of exchanged conflict tables. These are the remote DABS (REMD) and remote ATCRBS (REMA) lists. A single entry on one of these lists applies to a single aircraft. The entry is a subset of the aircraft state vector. An entry on these lists is accessed either directly with a pointer or through a cross-reference with an aircraft ID (either a DABS code or the same type of ATCRBS ID used with CREFX).

It will often happen that a remote ATARS will pass a seam conflict table that includes one or more aircraft which are not within the local data base. The local ATARS must retain these aircraft in the conflict tables as place-keepers so that, when the local ATARS is required to perform conflict resolution on an aircraft in this conflict table which is in the local data base, an accurate conflict table exists. The local ATARS is not required to process these remote aircraft in any other way. Hence, the entries in REMD and REMA serve essentially as abbreviated state vectors.

The REMFLG in the conflict table entry registers the current remote status of the aircraft to which that entry refers. If REMFLG is set, the ACID field in that conflict table entry points to an entry in REMD or REMA instead of to a state vector. REMFLG is not transmitted in the conflict table message because each ATARS must determine for itself if a particular aircraft is remote.

The local ATARS determines the value to be used for NAC in the conflict table head of a received conflict table by counting the number of conflict table entries. This field is not transmitted in the conflict table exchange message.

12.2 Conflict Table Exchange Using CIR

Since all ATARS-equipped aircraft have a CIR, the information contained therein is always used to update and exchange conflict information. This data exchange is primary for purposes of coordination with BCAS, and for confirming that own ATARS resolution advisories were received (see Section 5.3 for both of these); and for determining the current multi-site seam status of the aircraft in Geographical Processing Routine (see Section 6.3). When ground communication lines are installed and operating, the CIR exchange is secondary for multi-site ATARS. When no ground lines are available, the CIR becomes the primary method of coordination.

All resolution advisories sent to an aircraft are stored in the CIR (unless rejected for incompatibility). All CIR rows are read every scan by every ATARS site providing service to the aircraft. In this way, one site can learn of another site's action affecting aircraft in the seam. Although the conflict information exchanged this way (see Table 5-2) is less detailed than that exchanged over ground lines, it contains sufficient information to ensure selection of compatible advisories.

Every CIR row contains a field (the B/C field) indicating the system responsible for that row. Table 12-3 lists the values for this field. A BCAS row may only be updated by BCAS, and an ATARS row only by the same ATARS site which created it. The ATARS sites are indicated by their 4 bit ID.

Normally, the ATARS site originally resolving a conflict continues the resolution to the conflict end. This is true even when the pair flies into a seam area where another site would normally have higher priority. However, when an aircraft leaves a site's service area, that site must release its CIR rows for pairs involving this aircraft. This action is called a "handoff" in the flow charts, but is unrelated to ATC handoffs. The site releasing its CIR rows sends a message to any neighboring sites indicated in the aircraft GEOG variable, if ground lines are available. This action gives the neighboring sites an opportunity to assume responsibility for the pair immediately. If the ground line is not available, a neighboring site learns of the pair's availability when it reads the CIR.

12.3 Remote CIR Data Exchange

When own-site fails to read an aircraft's CIR data, it requests this data from another site (the "receiving site") connected by a ground communication line. This request is totally independent of the conflict table exchange described above; it is made even when the subject aircraft is not known to be in any conflict. This start/stop request is an ATARS-ATARS message passed through the Remote Site Coordination Buffer. The message format is shown in Table 12-4.

The ATARS receiving this request executes the Process Request for CIR Data Routine, shown in Figure 12-4. If the aircraft is in the seam of the requesting and receiving sites' coverage, the receiving site's DABS should already be enabled to read the aircraft's CIR. If not, the sensor is told to do so, and to borrow the requesting site's ATARS ID for this aircraft. Any messages the requesting site could not uplink are also sent to the sensor.

After the receiving site reads down the aircraft CIR contents, the CIR Processing Task (see Section 5.3) sends the data to the requesting site. If the request specified that only one scan of data was desired, as indicated by the one scan flag (OSCFL), the CIR Processing Task calls the Stop Remote CIR Data Routine, shown in Figure 12-5. Otherwise, CIR data is returned each scan until the requesting site sends a message to stop remote CIR data, the receipt of which executes the same routine. This routine stops

TABLE 12-3

RESPONSIBILITY FIELD IN CIR ROW

VALUE OF B/C FIELD	MEANING
1 1 1	BCAS responsible
1 1 0	Spare
1 0 1	ATARS row, handoff condition
1 0 0	ATARS site 1000 responsible
0 1 1	ATARS site 0100 responsible
0 1 0	ATARS site 0010 responsible
0 0 1	ATARS site 0001 responsible
0 0 0	No resolution established

TABLE 12-4

FORMAT OF START/STOP REMOTE CIR DATA MESSAGE

FIELD	BITS	MEANING
OWNID	4	ATARS ID of site requesting data
NID	4	Neighboring site ATARS ID
ACID	24	DABS Address of subject aircraft
START/STOP	1	Request to start or stop sending data
OSCFL	1	Only one scan of CIR Data is requested

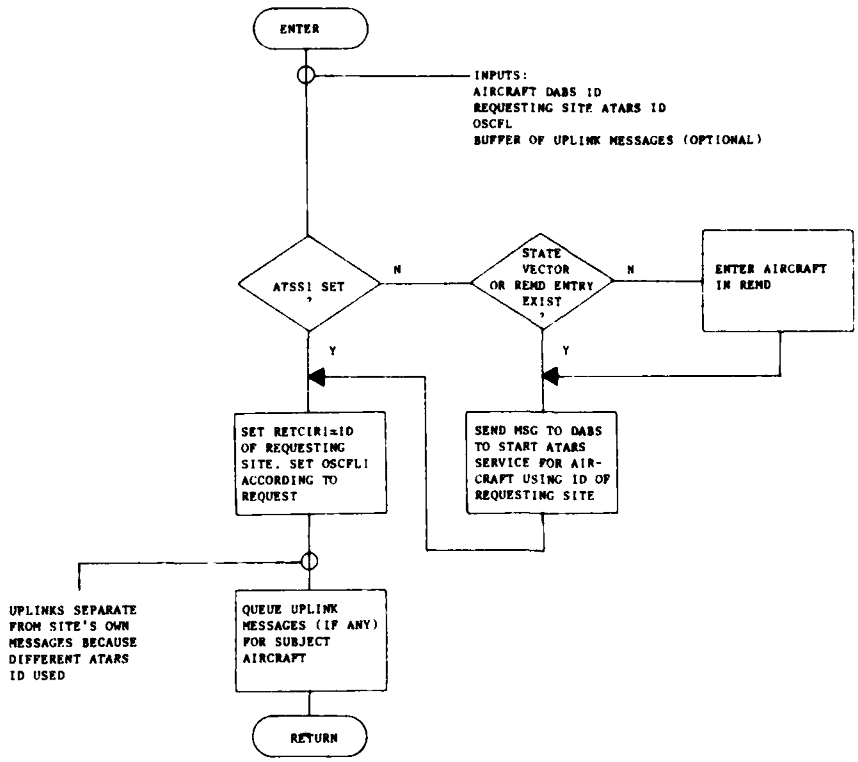


FIGURE 12-4
PROCESS REQUEST FOR CIR DATA ROUTINE

the sensor from collecting CIR data, unless the receiving site's ATARS is also providing service to the aircraft.

12.4 State Vector Deletion

This task (Figure 12-6) processes aircraft on the Deletion List and removes the aircraft state vector from CTS if appropriate. (This list should not be confused with the Resolution Deletion Encounter List.) An aircraft may be put onto the Deletion List in three ways.

1. By the Track Update Routine if DABS has lost surveillance contact with the aircraft.

2. By the Track Update Routine if missed reports have caused the ATARS track firmness to drop below the level needed to qualify for ATARS service.

3. By the Report Processing Task if the track is seen to have left the ATARS/domino service mask.

If the aircraft is still contained in a conflict table, a REMA or REMD entry is created at the time the state vector is deleted. If ATARS has some unfinished business with the aircraft such as a handoff message to be sent, state vector deletion is delayed.

12.5 Conflict Table Seam Status

Each conflict table contains a seam flag. This flag helps the Seam Pair Task recognize pairs involved with more than one ATARS site and delay resolution until coordination is performed.

The Conflict Table Seam Addition Task, shown in Figure 12-7, is performed after the Geographical Processing Routine updates each aircraft's GEOG variable. This task searches every non-seam conflict table. If any aircraft is found whose GEOG indicates coverage by a site other than own (other than own or failed site, when own-site is the master site), the seam flag is set.

The Conflict Table Seam Deletion Task, shown in Figure 12-8, is performed after delayed resolution, pair removal, and state vector deletion. This task searches all conflict tables in memory which have the seam flag set. If any are found which are entirely interior to own-site and not involved with a seam, the seam flag is reset. If any are found which are entirely exterior, that is, only contain remote aircraft, the conflict table is deleted. These conditions can come about when seam pairs are deleted, and the only remaining pairs in the conflict are all interior or all exterior.

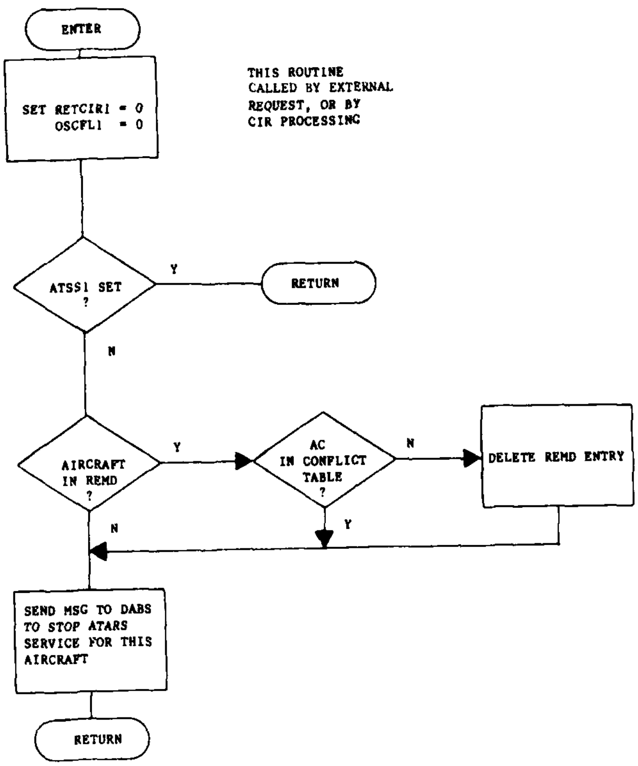


FIGURE 12-5
STOP REMOTE CIR DATA ROUTINE

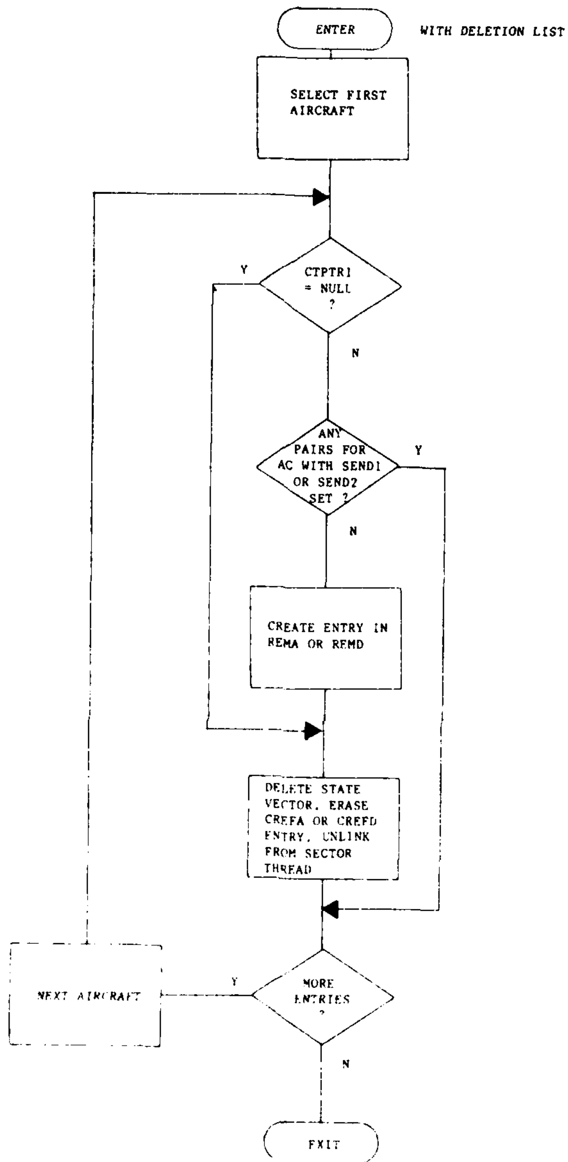


FIGURE 12-6
STATE VECTOR DELETION TASK

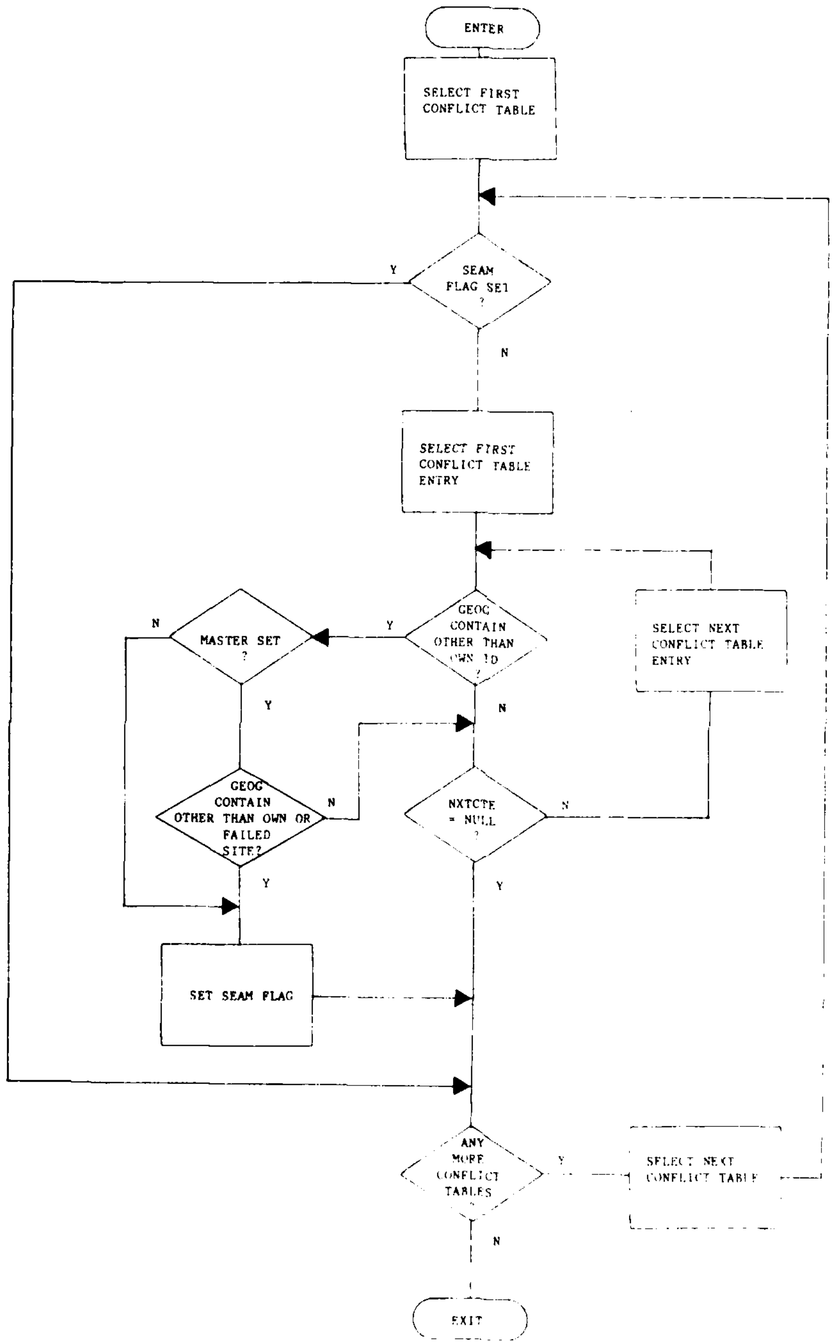


FIGURE 12-7
CONFLICT TABLE SEAM ADDITION TASK

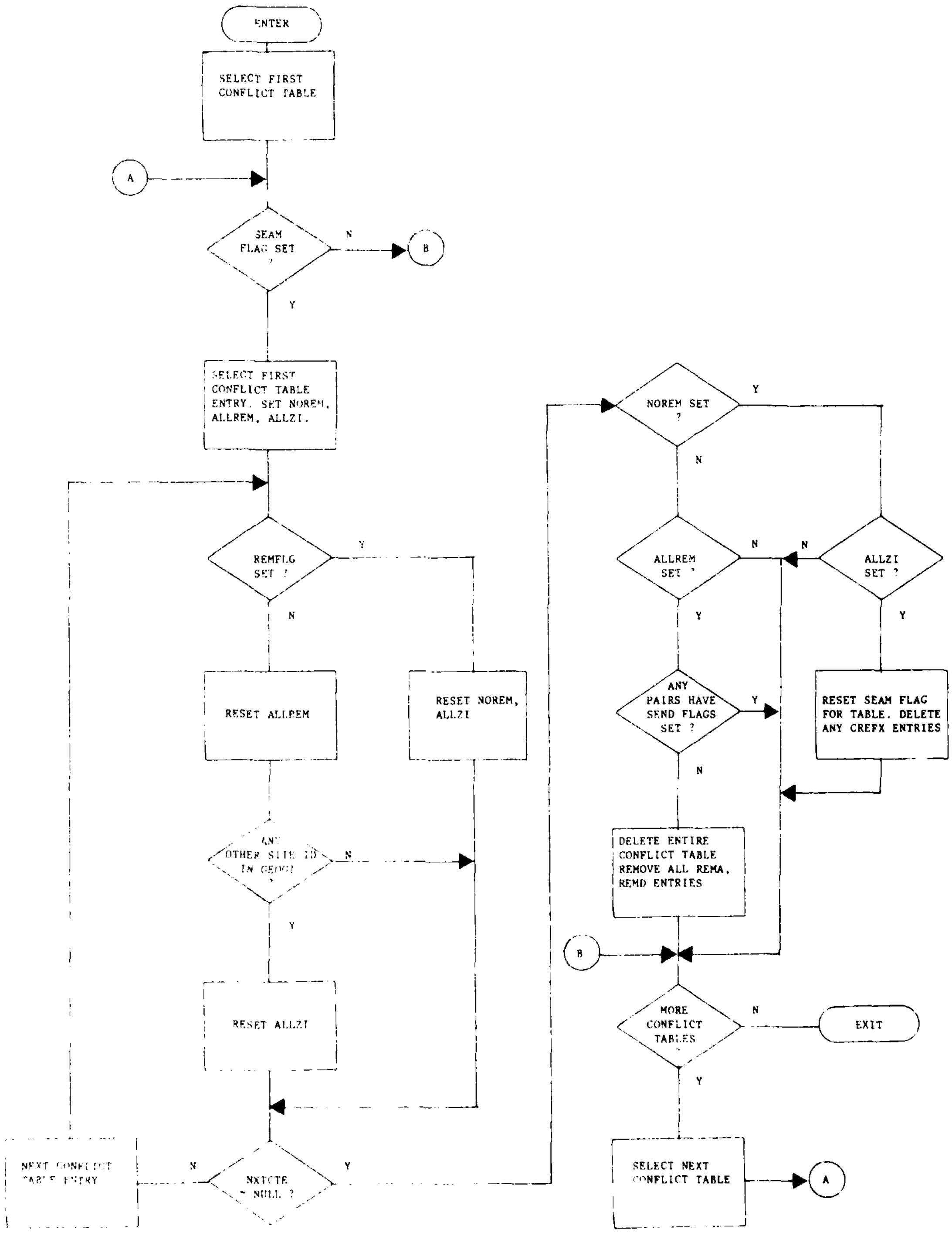


FIGURE 12-8
CONFLICT TABLE SEAM DELETION TASK

13. CONFLICT PAIR REMOVAL

The Conflict Pair Removal Task ensures that each conflict resolved by the local site is closed out in the proper manner when the conflict is over and that conflict data stored in the pair records is deleted when it is no longer needed. The main flow chart for the Conflict Pair Removal Task is given in Figure 13-1 and is described in Section 13.1. The deletion of all pair records is handled by the Pair Record Deletion Routine, which is described in Section 13.2. This routine is called from the Conflict Pair Removal Task, as well as from several other tasks.

13.1 Conflict Pair Removal (Main Task)

The Conflict Pair Removal Task examines each pair record associated with the current sector. If a pair record has already been processed on this scan (PWISF set), then no further processing takes place. If processing has not already occurred, then this task checks for two basic conditions: (1) an aircraft has just flown out of the coverage area of the local site, and (2) the local site has assumed responsibility for the pair, but is no longer calling for resolution advisories.

When an aircraft is discovered to have flown out of coverage of the local site, all resolution advisory information pertaining to that aircraft can be cleared out of the conflict table. This may mean that a pair record involving that aircraft can be deleted immediately.

For a conflict where the local site had responsibility, but is no longer calling for resolution advisories, the following logic is performed: First, the sector ID is updated for the pair. The Update Sector ID Routine is described in Section 5.3.5. If the local site is attempting to uplink null advisories or handoff messages, the pair record is left with no further change so that this effort may continue. Likewise, if positive resolution advisories were previously selected and they have not been uplinked for the minimum time period, then the pair record is also left without further change. If the local site is no longer detecting a conflict solely because one aircraft flew out of the coverage area of the local site (into an area not covered by an adjacent site), and if the aircraft remaining in coverage is equipped with BCAS, then the SEND flag for the BCAS aircraft is reset, and no further resolution advisories of any kind are uplinked for the conflict. This allows either the existing advisories to time out or BCAS to take over responsibility for resolving the conflict. In all other cases where the local site

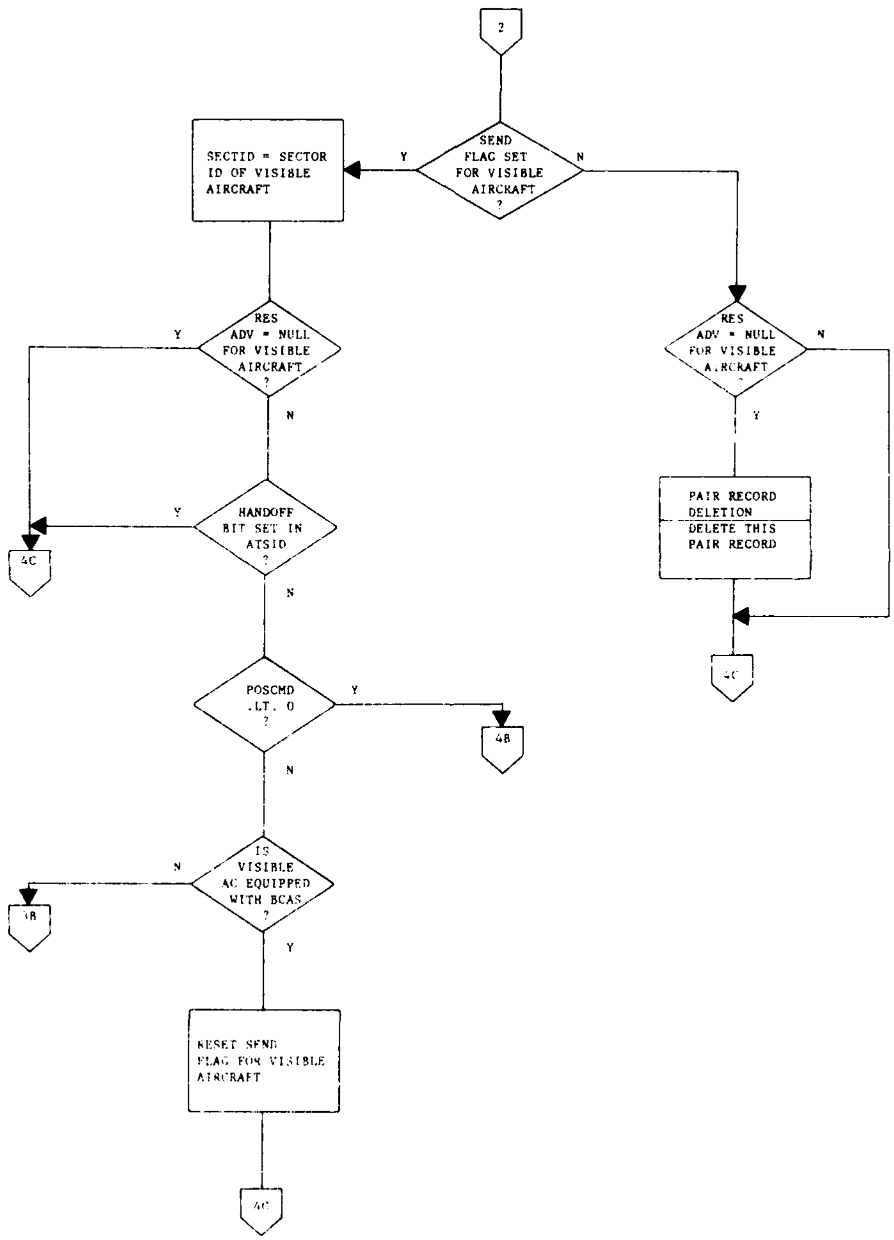


FIGURE 13-1
CONFLICT PAIR REMOVAL TASK (Page 2 of 4)

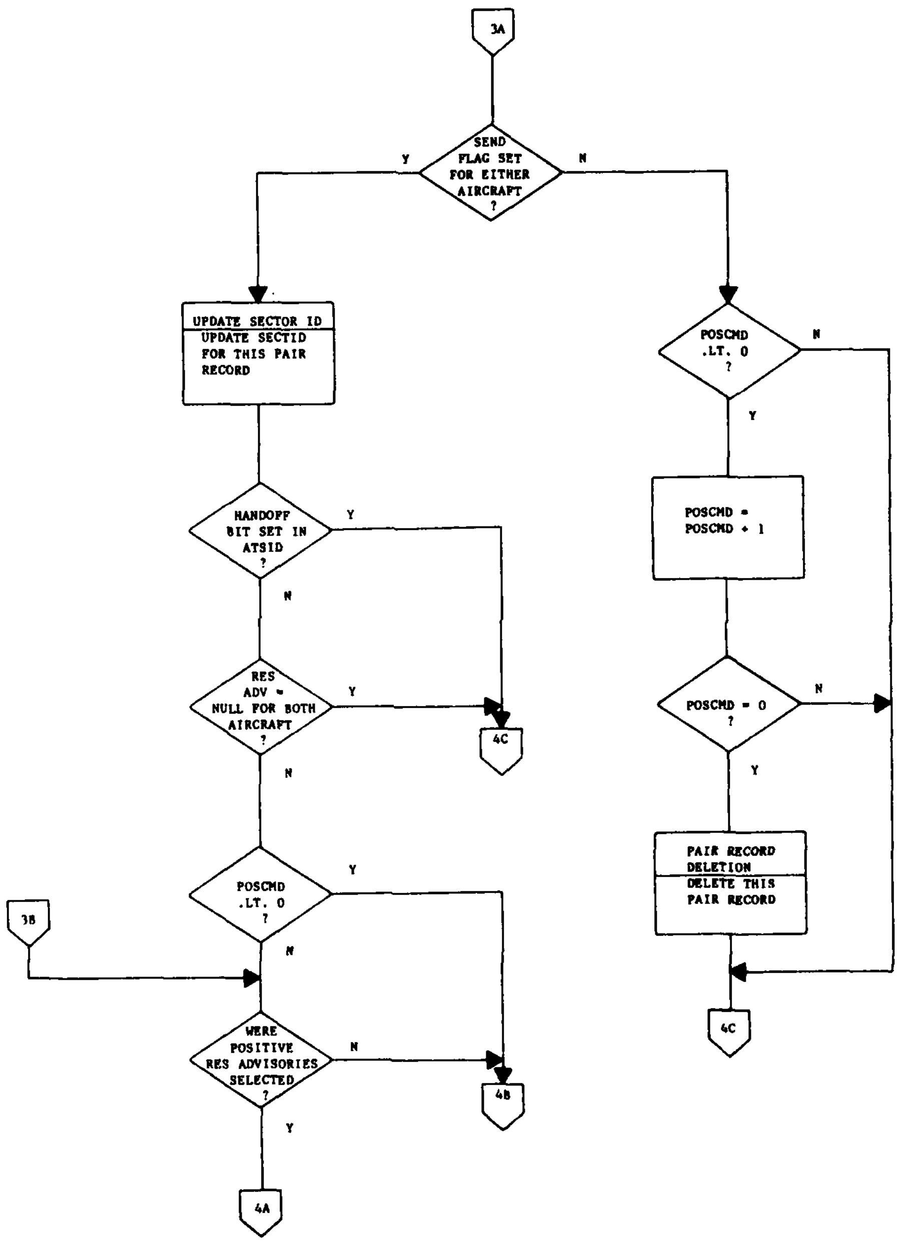


FIGURE 13-1
CONFLICT PAIR REMOVAL TASK (Page 3 of 4)

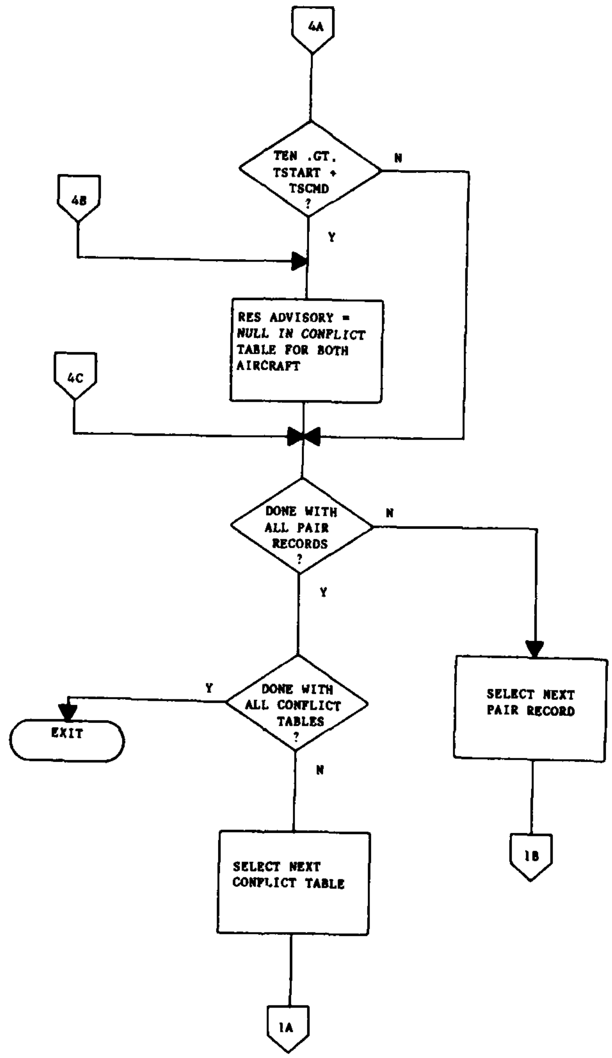


FIGURE 13-1
CONFLICT PAIR REMOVAL TASK (Page 4 of 4)

had responsibility, null resolution advisories are placed in the conflict table for subsequent uplink to one or both aircraft.

In some instances, a pair record may be found where the local site has assumed responsibility, initial resolution advisories have not yet been selected, and PWISF is not set. This implies that the 2-out-of-3 rule for initial resolution advisories has not been satisfied and that the detection logic is not calling for resolution on this scan. In this case, the Conflict Pair Removal Task implements a part of the 2-out-of-3 logic by incrementing POSCMD and deleting the pair record if POSCMD has reached zero.

13.2 Deleting a Pair Record

The process of deleting a pair record when a pair which was previously in conflict finally clears the conflict requires special attention, for it is possible that a multi-aircraft conflict table may split into two separate conflict tables. It is then necessary to determine which aircraft belong in each conflict table.

Once it has been determined that a pair has cleared the conflict, that pair record is deleted and the conflict table entries for one or both aircraft may be deleted from the conflict table. The resultant conflict table is still a single structural item, even though it may consist of two logically independent conflict tables. A temporary linked list of aircraft pair ID's is created by extracting all remaining pair ID's from the pair list of the subject conflict table. The process of building up the residual conflict table(s) begins by considering the current conflict table head to be the table head for the first new conflict table and by automatically assigning the first conflict table entry to this table. All aircraft in pairwise conflict with this aircraft must go in the first table also.

Call the list of pair ID's list A and create another list of aircraft ID's called list B. This list is a list of all aircraft which have been identified for inclusion in the first conflict table. A third list, list C, is a list of all pairs which belong to the first conflict table.

A pointer to an entry on list B gives the first aircraft for which a scan for pair conflicts involving that aircraft has not yet been made through list A.

The ID of the aircraft in the first conflict table entry is added to list B. List A is scanned for pairs involving this aircraft. The ID's of the second aircraft in these pairs are placed on list B. These pairs are then removed from list A and placed on list C. Next, the pointer is moved down list B to the next ID. The process of scanning list A is repeated. If list A is exhausted before the pointer reaches the end of list B, there has been no split of the conflict table. If the pointer reaches the bottom of list B first, there has been a split. All aircraft on list B and all pairs on list C belong to the first conflict table and all remaining aircraft and the pairs on list A belong to the second conflict table. (With the breakup of a single pair only, there can be at most two residual conflict tables.)

The detailed flow chart for deleting a pair record is given in Figure 13-2. Once the pair record has been deleted, the NCON field in the conflict table entry of each aircraft in the pair is reduced by one.

If NCON is not equal to zero, then the conflict table entry should not be deleted. In this case, the intermediate maneuver table should be checked. If the pair record being deleted is causing a resolution advisory, then delete the resolution advisory from the intermediate maneuver table, decrement MULTH or MULTV, and set HMAN or VMAN to the highest priority of the remaining resolution advisories, or null if there are no resolution advisories in that dimension. Section 9.7 describes the manner in which the resolution advisory is chosen for the conflict table entry.

If the NCON field of either of the aircraft's conflict table entries has gone to zero, that aircraft is involved in no other conflict pair, and its conflict table entry is completely deleted. If REMFLG was set in the conflict table entry, then the remote list entry for the aircraft can be deleted. Otherwise, the CTPTR and CTE fields in the aircraft's state vector are reset to null.

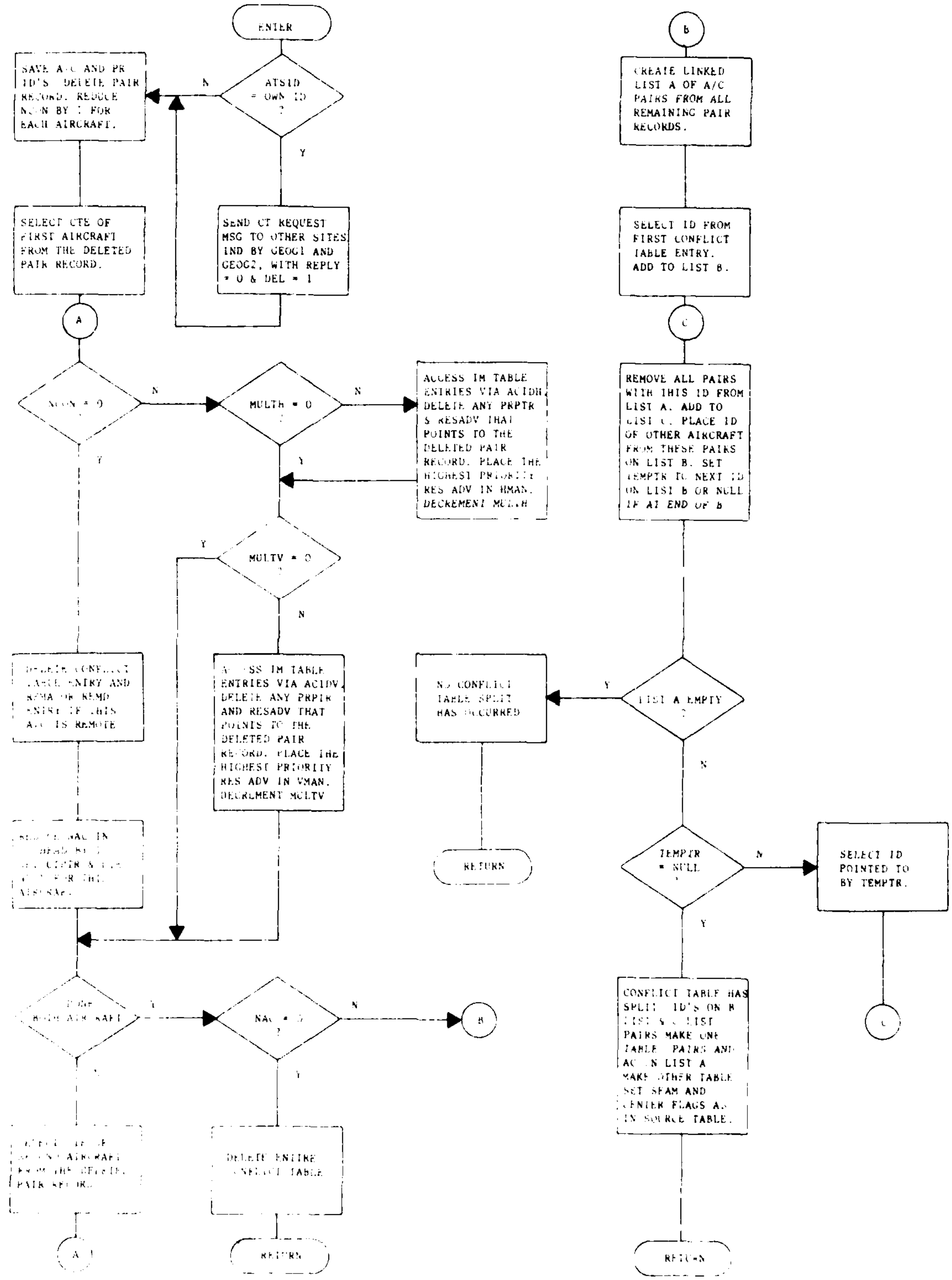


FIGURE 13-2
PAIR RECORD DELETION ROUTINE

14. DATA LINK MESSAGE CONSTRUCTION

The Data Link Message Construction Task generates all messages required for each aircraft. Three types of messages may be generated (one type for conflicts, and two types where no conflict exists). First, if the aircraft is in conflict, any Resolution, Threat, or Proximity Advisory Messages required are generated. Second, if the aircraft is a new entry in the ATARS data base, an Own Message is generated, and third, if the aircraft is near the ground, an obstacle, or in a restricted airspace, an alert message is generated and a duplicate Controller Alert Message is sent to the ATC facility.

14.1 Conflict Messages

All conflict messages are generated from data stored in the PWILST during the Data Link Message Pre-processing Task (discussed in Section 8). At the conclusion of data link message pre-processing, the PWILST has accumulated entries containing all data required for messages. Each entry has been categorized by conflict (encounter) type into resolution, threat or proximity classes, but the categories are not sorted by type, the entries within each category are not sorted, and more data may exist than can be accommodated by the DABS sensor.

The sequence of messages generated is determined by the order of entries in the PWILST, thus, further processing of the PWILST must occur before messages can be generated.

14.1.1 Sorting, Ranking, Establishing the Most Critical Entry in the PWILST

Each entry in the PWILST has an encounter type recorded in the header segment. As discussed in Section 8, these types may be R, TR, TN, T, or P. Any of these types may have the End Flag (ENDFLG) set if the entry was not updated on this scan. Type R entries with ENDFLG set are moved to the top of the set of resolution entries. Other types with ENDFLG set are moved to the end of the PWILST and the type is changed to E for end encounter. All types with ENDFLG not set are sorted by encounter type.

Within each threat or proximity encounter category, where two or more threat or proximity encounters exist, the message sequence is determined from the ranking of each aircraft. This ranking is based conceptually on the severity of the encounter and is a number which provides a mechanism for sorting the encounters and choosing the most critical encounter.

The ranking for several threat encounters is based first on the threat category, second on the value of horizontal tau within the category and third on the value of range within one horizontal tau category. The highest ranking encounter is defined as the one with the lowest tau (or range if used).

Threat encounters are divided into two categories: threats that also require resolution (based on the severity of the encounter) and threats that do not require resolution. Within each of these two categories, tau is computed using the rules below.

1. When the MTTFLG is set in the Detect Task, a "pseudo-tau" is computed from the horizontal range divided by the sum of the two aircraft velocities.

2. Where threats are diverging, a large constant is assigned to tau (LRGTAU).

3. When neither of the two cases above is true, tau is the same value computed in the Detect Task.

If two or more threat encounters within one category have the same horizontal tau, these encounters are ranked on the basis of range between the two aircraft where vertical separation is weighted by a factor of five relative to lateral separation.

The ranking for several proximity encounters is based on the range between the two aircraft where vertical separation is weighted by a factor of five relative to lateral separation. The highest ranking encounter is defined as the one with the lowest numerical range.

When ranking is completed, three sorted categories of threat and proximity encounters may exist:

1. threats that require resolution,

2. threats that do not require resolution, and

3. proximities.

For the purpose of selecting the most critical encounter, these three categories are consolidated into threats and proximities. Selection of the most critical encounter is based on two rules.

1. An encounter displayed to the pilot as most critical must continue to be displayed for two scans unless a higher encounter category exists.

2. Encounters in the threat category are more critical than encounters in the proximity category.

When encounters exist in both categories, the most critical encounter is the highest ranking threat encounter unless a lower ranking threat encounter exists that was previously selected as most critical one time but not more than two times. If this low ranking previously most critical threat exists, it is selected as most critical. Low ranking threat encounters selected as most critical using the two times rule are moved to the top of the rank order. If a proximity encounter exists that was previously selected most critical, it is replaced as most critical by the new threat encounter.

When encounters exist in only one category, the most critical encounter is the highest ranking encounter in the category unless a lower ranking encounter in that category exists that was previously selected as most critical one time but not more than two times. If this low ranking previously most critical encounter exists, it is selected as most critical. Low ranking encounters selected using the two times rule are moved to the top of the rank order.

If a message based on an encounter that is marked most critical is not successfully delivered, the encounter does not need to be marked most critical the next time unless it appears at the top of the rank order based on tau or range alone.

After the PWILST is sorted, ranked and arranged by most critical, the list will be in the order shown in Figure 14-1.

14.1.2 Assigning Track Numbers, Deleting Entries Without Numbers in the PWILST

After the PWILST is arranged in order, each encounter is assigned a track number (PWINO) from zero to seven. If more than eight encounters exist, any old encounters that rank below eight in the list may be deleted and the numbers reassigned to new entries, or any new entries without numbers ranking below eight in the list may be deleted. In the special case when two list entries exist for a paired TR/R (threat and resolution) case, the track number is the same for both entries and must be assigned to both entries when they are new.

14.1.3 Establishing Message Contents From Entries in the PWILST

Although the sequence of messages is determined from the order of the PWILST, the data in the message delivered to the aircraft

Resolution Entries	R (END)	
	R	Selected at Time 1
	R	Selected at Time 2
Threat Entries	TR	Tau 1
	TN	Tau 2
	T	Tau 3, Range 1
	T	Tau 3, Range 2
Prox Entries	P	Range 1
	P	Range 2
	P	Range 3
Prox, Threat Entries	P (END)	
	TR (END)	
	P (END)	
	TN (END)	
	T (END)	

FIGURE 14-1
DESCRIPTION OF ORDERED PWILST AFTER THE SORT AND SET CRITICALITY ROUTINE ARE COMPLETED

depends on the exact encounter status (types and number of PWILST segments) at the time the message is delivered.

If two Proximity Segments exist in the PWILST, the position data from the first segment is combined with the position data from the second segment to form a single message for the aircraft. If an Own Message is required the own data may be combined with start threat data (if start threat is required) or with position or supplementary data (where a proximity is required) to form a single message. Table 14-1 shows an example of advisory message contents for four encounters.

The message types shown in the example are a subset of the types of messages that may occur. Table 14-2 provides a list of all message types currently defined. As shown in this table, 14 different message types currently exist. The conflict messages include three resolution messages (ADS #59, 61, 63), two threat messages (ADS #29, 30), and five proximity messages (ADS #25, 26, 27, 28, 31). The remaining message types are non-conflict messages which are discussed in Section 14.2 below.

14.2 Non-conflict Messages

The two types of non-conflict messages that may be generated are the Own Message (ADS #24) and alert messages for terrain, obstacle or restricted airspace (ADS #16, 17, 18). The own message data verifies proper operation of the DABS sensor and transponder and informs the pilot that he is within ATARS coverage. The data may also be used to display ATARS ground track heading, velocity and turn rate. The contents of the Own Message is shown in Tables 14-3 through 14-5. The alert messages for obstacles, terrain, or restricted airspace are information messages for the pilot.

14.3 Message Construction Summary

The Data Link Message Construction Task is subdividied into three major parts: Compute Criticality Routine, Message Construction Routine, and the Final Message Processing Routine. Compute criticality includes the following steps:

1. sort in order by type and rank,

2. mark the most critical threat or proximate encounter,

3. assign track numbers for new entries, and

TABLE 14-1

MESSAGES REQUIRED FOR AN ENCOUNTER
(No Threats, 6 Proximities, Own Required)

MESSAGE TYPE	ADVISORY MESSAGE	
	DATA IN FIELD1	DATA IN FIELD2
DUAL PROXIMITY	POSITION	POSITION
DUAL PROXIMITY	POSITION	POSITION
DUAL PROXIMITY	POSITION	POSITION
OWN+SUPPLEMENTARY	OWN	SUPPLEMENTARY

(2 Threats, 3 Proximities, Own Not Required)

MESSAGE TYPE	ADVISORY MESSAGE	
	DATA IN FIELD1	DATA IN FIELD2
THREAT	BASIC THREAT	POSITION
THREAT	BASIC THREAT	POSITION
DUAL PROXIMITY	POSITION	POSITION
SINGLE PROXIMITY	POSITION	SUPPLEMENTARY

(No Threats, 6 Proximities, Start Prox Required, Own Required)

MESSAGE TYPE	ADVISORY MESSAGE	
	DATA IN FIELD1	DATA IN FIELD2
START PROXIMITY	START	POSITION
DUAL PROXIMITY	POSITION	POSITION
DUAL PROXIMITY	POSITION	POSITION
OWN+PROXIMITY	POSITION	OWN

(2 Threats, Start Threat Required, 3 Proximities, Own Required

MESSAGE TYPE	ADVISORY MESSAGE	
	DATA IN FIELD1	DATA IN FIELD2
THREAT	BASIC THREAT	POSITION
START THREAT	START THREAT	OWN
DUAL PROXIMITY	POSITION	POSITION
SINGLE PROXIMITY	POSITION	SUPPLEMENTARY

TABLE 14-2

ADVISORY DEFINITIONS

MESSAGE TYPE*	PRIORITY	ADS (8 BITS)	FIELD 1 DATA (24 BITS)	FIELD 2 DATA (24 BITS)
Own	0	24	Own	Blank (Set = 0)
Own + Proximity	0	25	Position	Own
Start Proximity	0	26	Start/End	Position
Dual Proximity	0	27	Position	Position
Single Proximity	0	28	Position	Supplementary Proximate
Start Threat	0	29	Start Threat	Own
Threat	1	30	Basic Threat	Position
Own + Supplementary Proximity	0	31	Own	Supplementary Proximate
Resolution	1	59	DABS Resolution Advisory Format	
Resolution	1	61	ATCRBS Resolution Advisory Format	
Resolution	1	63	ATCRBS Track Block Format	
Terrain	1	16	DABS ID	Blank (Set = 0)
Obstacle	1	17	DABS ID	Blank (Set = 0)
Airspace	1	18	DABS ID	Alert Type Indicator

* See Reference 9.

TABLE 14-3

OWN DATA

FIELD	BITS	INTERPRETATION
Own Ground Track Heading (OGTH)	7	0° to 360°: (OGTH) * 2.8125° referenced to magnetic north of DABS site
Own Ground Track Speed (OGTS)	7	0 to 1270 kts: (OGTS) * 10 kts
Own Ground Track Turn Rate (OGTTR)	4	0 to + 7 degrees/second (two's complement with left (1) and right (0))
Own ATARS Capability	2	4 levels possible (only 01 used at present)
Seam Bit	1	Multi (1) or single (0) ATARS sites can uplink threat, proximate or own data
Time	3	Antenna scan period in seconds minus four, rounded to nearest integer. If period is greater than 11 seconds report as 7 (i.e., 111)
TOTAL	24	

TABLE 14-4

SOURCE OF OWN DATA

FIELD	SOURCE
Own Ground Track Heading (OGTH)	Table 14-5, Equation I
Own Ground Track Speed (OGTS)	Table 14-5, Equation II
Own Ground Track Turn Rate (OGTTR)	State vector
Own ATARS Capability	State vector
Seam Bit	GEOG field in state vector and Table 14-5
Time	Table 14-5, Equation VI

TABLE 14-5

OWN DATA FIELDS

I	Own Ground Track Heading (OGTH)	
	= INT (ARC COT (YD1/XD1)/2.8125°)	
	Note: Correct for proper quadrant	
II	Own Ground Track Speed (OGTS)	
	= INT (SQRT (VSQ1)/10 kts)	
III	Own Ground Track Turn Rate (OGTTR)	
IV	Own ATARS Capability (Code 01 is equipped)	
V	Seam Bit (Set to zero if GEOG field in the state vector = own-site)	
VI	SCANTM - 4.7 sec	

4. if more than eight entries exist, delete low ranking entries until only eight remain.

Message construction includes the following steps:

1. determine if an Own Message is required (according to Table 14-6), compute own data if needed, set OWNFL1,

2. set up UPLST/ACLST for a new message set,

3. determine the types of threat advisories required according to Table 14-7,

4. determine the types of proximity advisories required according to Table 14-8,

5. determine if end encounter advisories are required (if any exist in the PWILST), and

6. determine if an Own Message is required (based on the value of OWNFL1).

As each message is constructed, a relative pointer value is assigned to each message based on the current value of UPMES and the ADS message number is assigned as specified in Table 14-2.

Final message processing includes the following steps:

1. determine if obstacle, terrain or airspace alert messages are required (based on the value of flags),

2. if resolution messages exist in UPLST, insert the terrain, obstacle or airspace warning messages below the resolution messages,

3. generate terrain, obstacle or airspace Controller Alert Messages indicating a terrain, obstacle, or airspace alert, and

4. prepare all messages for uplink by assigning all header fields as specified in Figure 14-2.

Figures 14-3 through 14-12 provide additional detail on the logic of the Data Link Message Construction Task.

TABLE 14-6

OWN REQUIRED

An Own Message is required whenever any of the following conditions is true.

1. The seam bit setting has changed since the last Own Message was delivered successfully.

2. The absolute value of (Own Ground Track Heading (OGTH) minus aircraft's calculation of OGTH) is greater than OGHDIF, where aircraft calculation of OGTH is based on last Own Message OGTH plus (own ground track turn rate times the elapsed time since the last Own Message was successfully delivered).

3. The last Own Message sent was not successfully delivered.

4. A new aircraft is ready for ATARS processing (OWNFL1 set).

TABLE 14-7

START THREAT AND THREAT ADVISORY REQUIRED

Both a start threat and a threat advisory are required whenever any of the following conditions is true.

1. A new encounter (i.e. not transitioning from proximity status) STFLG set.

2. A threat encounter is transitioning from a proximity and an Own Message is required.

3. A threat encounter is transitioning from a proximity and the absolute value of (velocity of the threatening aircraft currently being used by ATARS on the ground minus the velocity of the threatening aircraft last transmitted to "own" aircraft) is:

   a. greater than THVPER times the velocity being used by ATARS and

   b. greater than THVDIF kts.

4. The last start threat advisory sent was not successfully delivered.

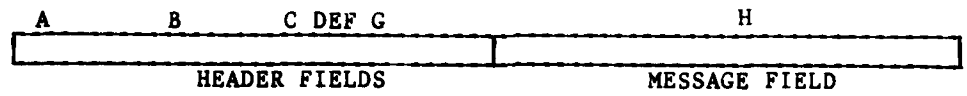
If none of the conditions requiring both a start threat and a threat advisory are true, a threat advisory is delivered.

TABLE 14-8

PROXIMITY MESSAGE TYPES REQUIRED*

ADS	MESSAGE NAME	CONDITION
25	Own + Proximity	An Own Message is required and one Proximity Segment remains after all dual proximities are paired.
26	Start Proximity	The last Start Proximity Message was not successfully delivered or the proximity encounter is new (STFLG set).
27	Dual Proximity	Two Proximity Segments exist.
28	Single Proximity	An Own Message is not required and one Proximity Segment remains after all dual proximities are paired.
31	Own + Supplementary Proximity	An Own Message is required and no Proximity Segments remain after all dual proximities are paired.

* Tnese conditions must be checked in the order ADS #26, 27, 25, 28 and 31 as shown in Figure 14-10 (Enter Proximity Advisories Routine)



FIELD	BITS	FIELD DESCRIPTION*
A	8	Message Type Code (mono-link = 1010 0001)
B	24	DABS Address (24 bit ID code for DABS aircraft)
C	4	Message No
D	1	Priority (see Table 14-2)
E	3	Expiration Time (always = 1 scan)
F	4	ATARS Site Identification Code of Sending Site
G	8	ADS Code (see Table 14-2)
H	48	Message (see Table 14-2)

* See Reference 8.

FIGURE 14-2
ATARS-TO-LOCAL SENSOR UPLINK MESSAGE FORMAT

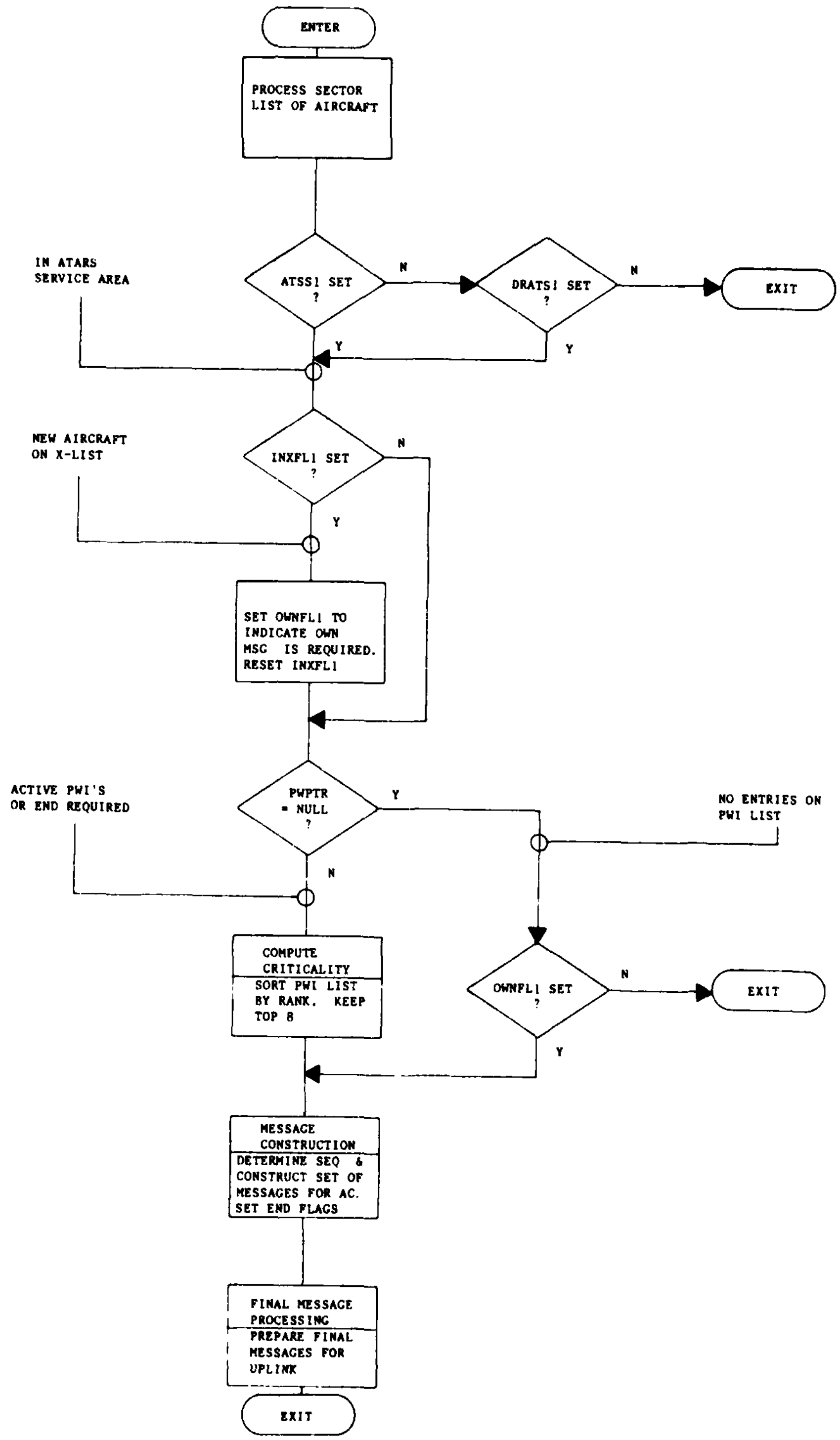


FIGURE 14-3
DATA LINK MESSAGE CONSTRUCTION TASK

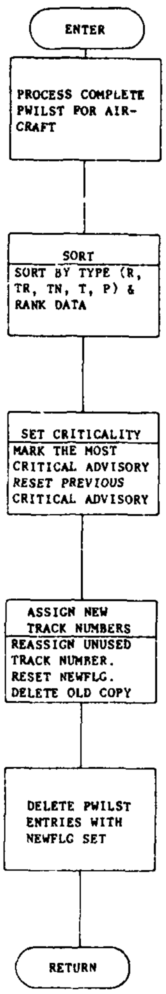


FIGURE 14-4
COMPUTE CRITICALITY ROUTINE

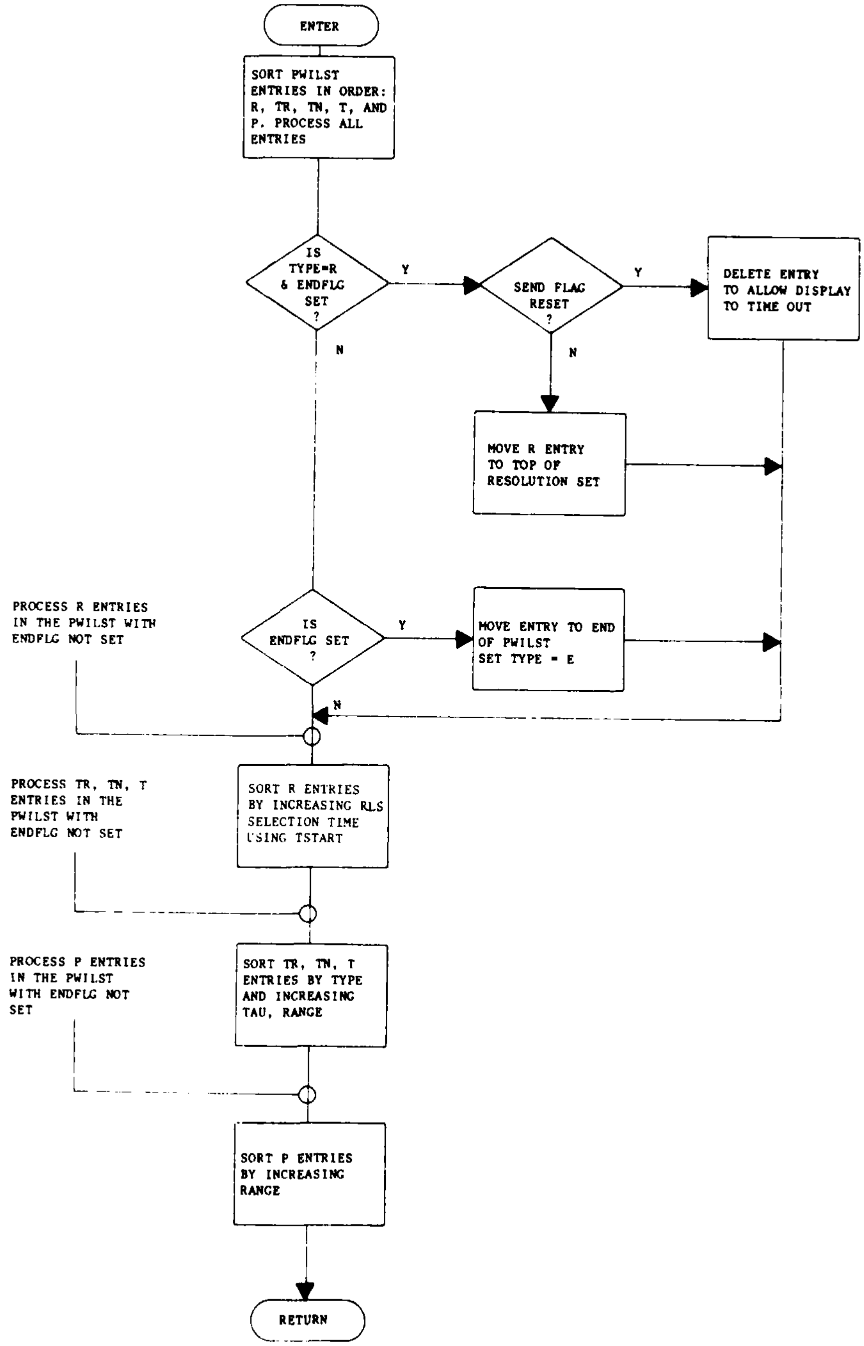


FIGURE 14-5
SORT ROUTINE

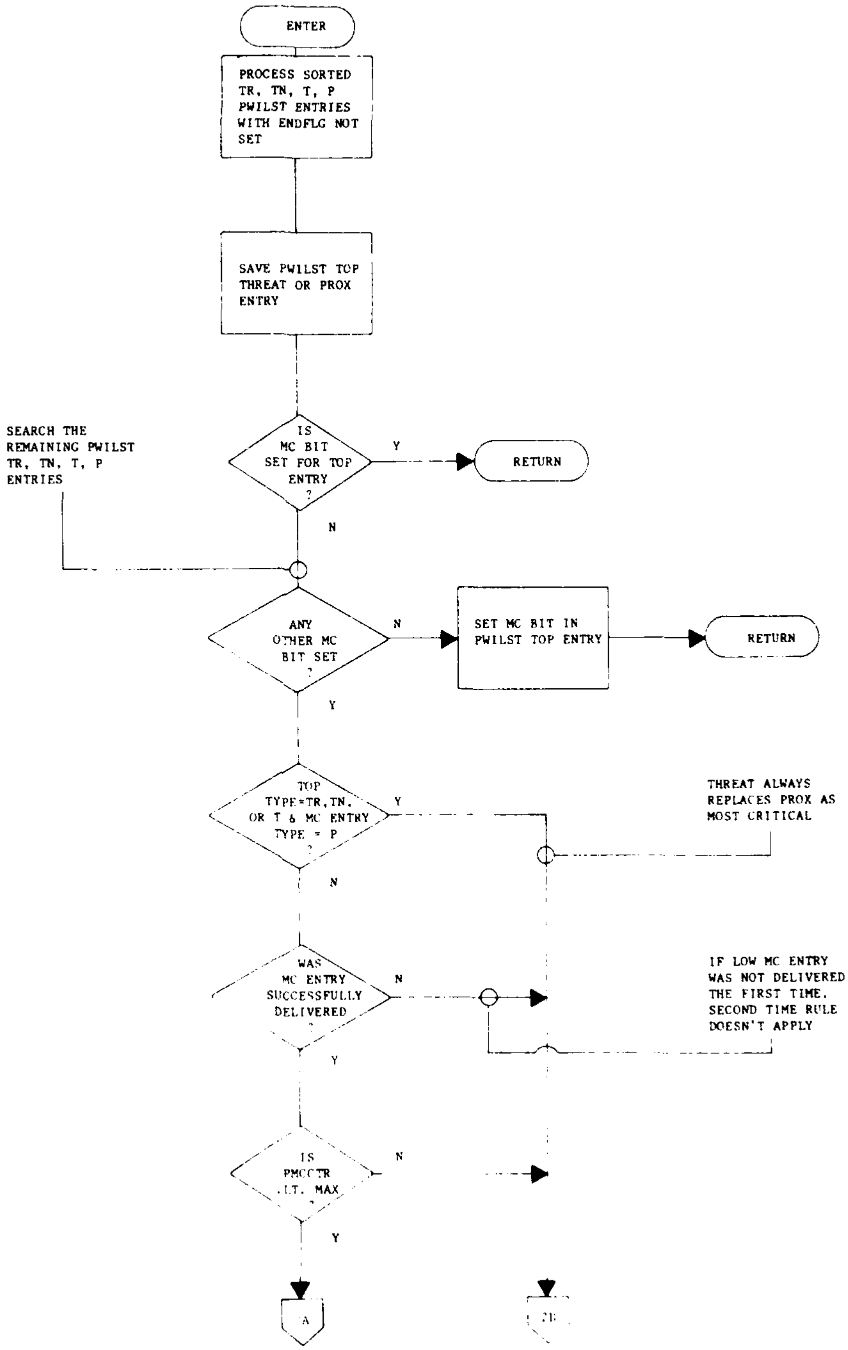


FIGURE 14-6
SET CRITICALITY ROUTINE (Page 1 of 2)

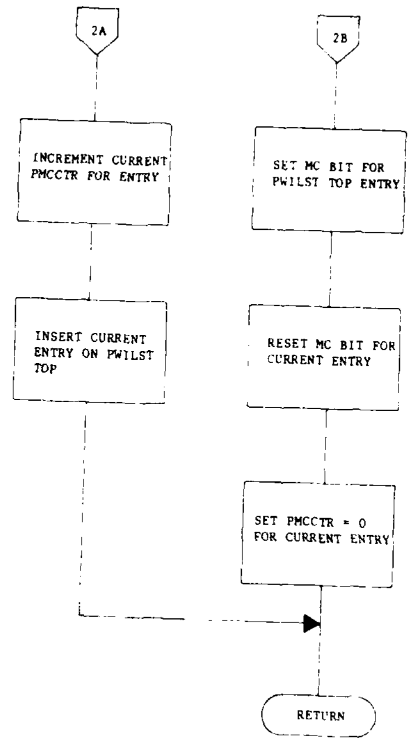


FIGURE 14-6
SET CRITICALITY ROUTINE (Page 2 of 2)

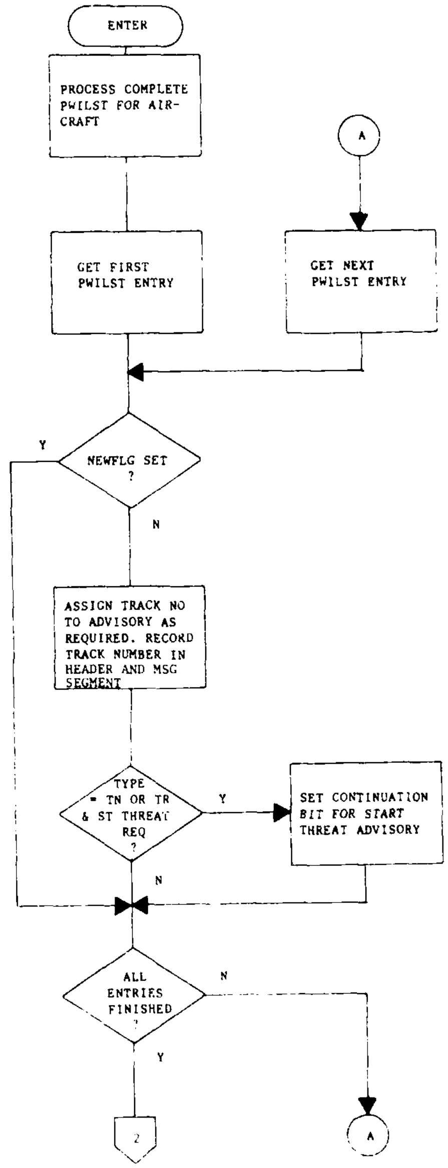


FIGURE 14-7
ASSIGN NEW TRACK NUMBERS ROUTINE (Page 1 of 4)

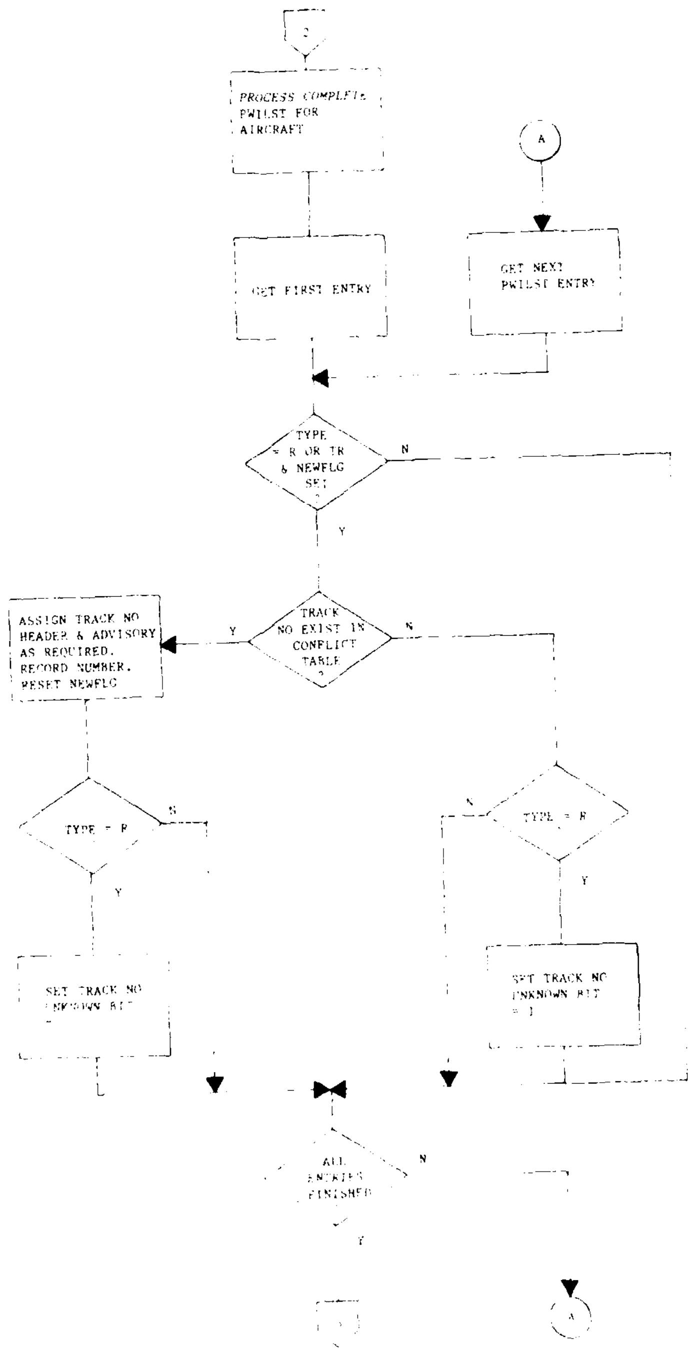


FIGURE 14-7
ASSIGN NEW TRACK NUMBERS ROUTINE (Page 2 of 4)

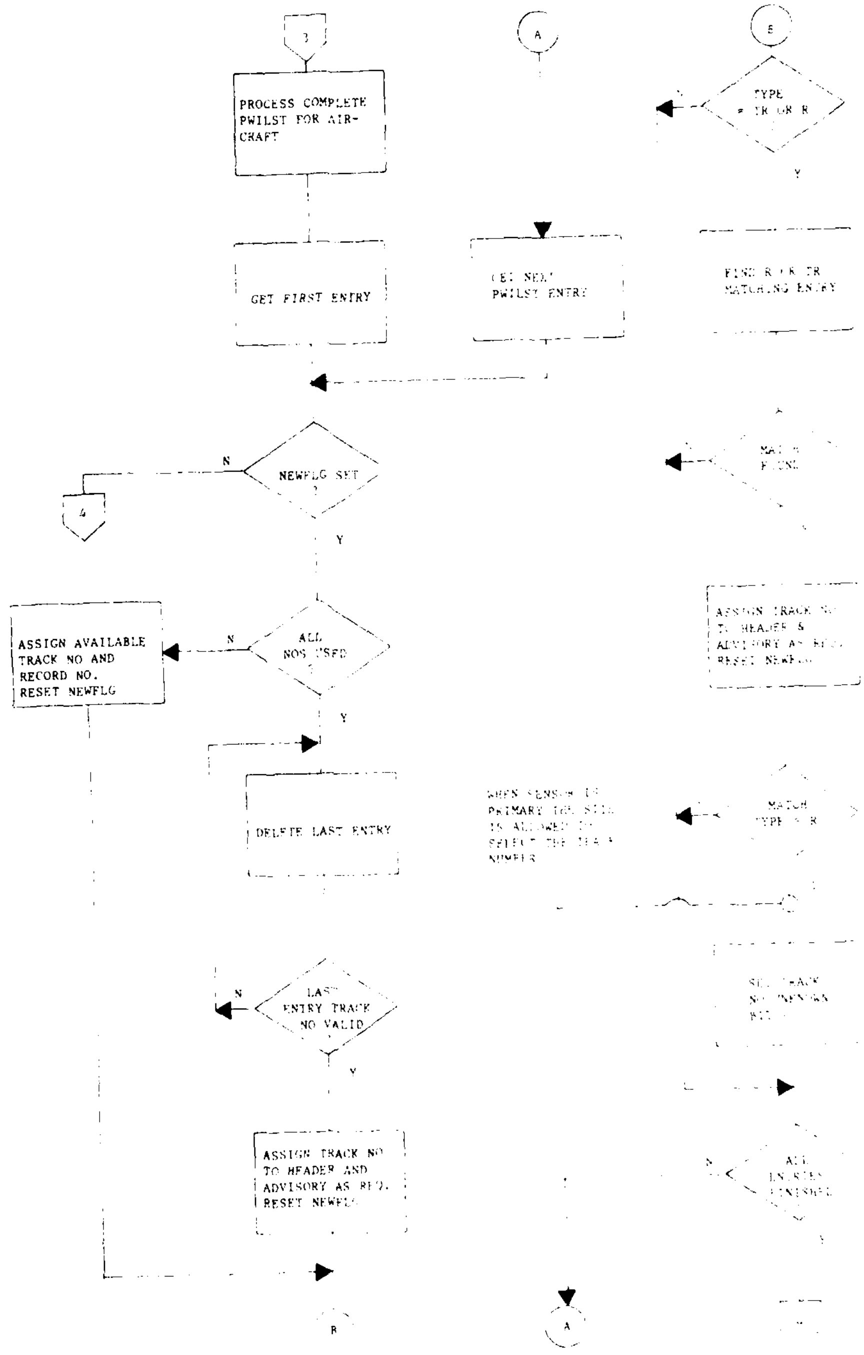


FIGURE 14-7
ASSIGN NEW TRACK NUMBERS ROUTINE (Page 3 of 4)

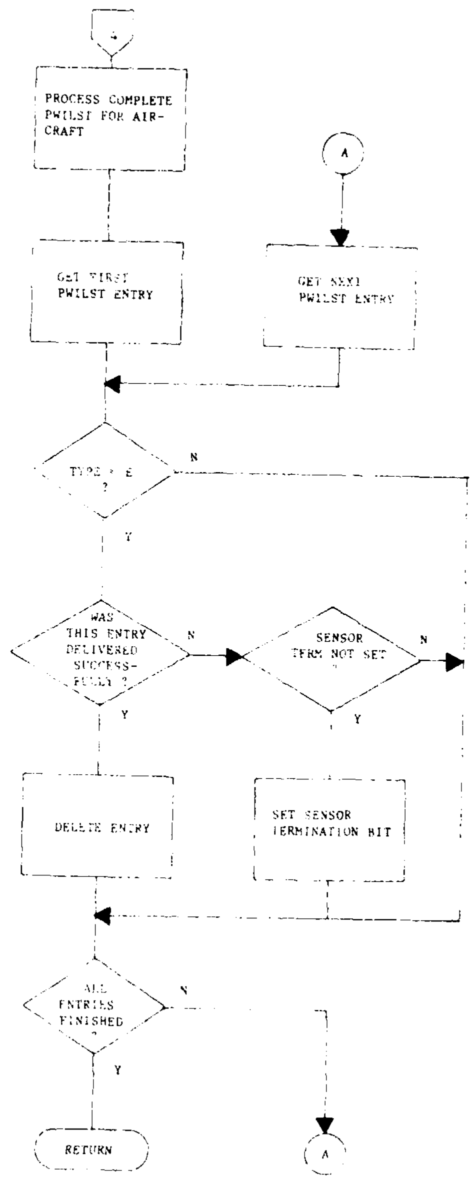


FIGURE 14-7
ASSIGN NEW TRACK NUMBERS ROUTINE (Page 4 of 4)

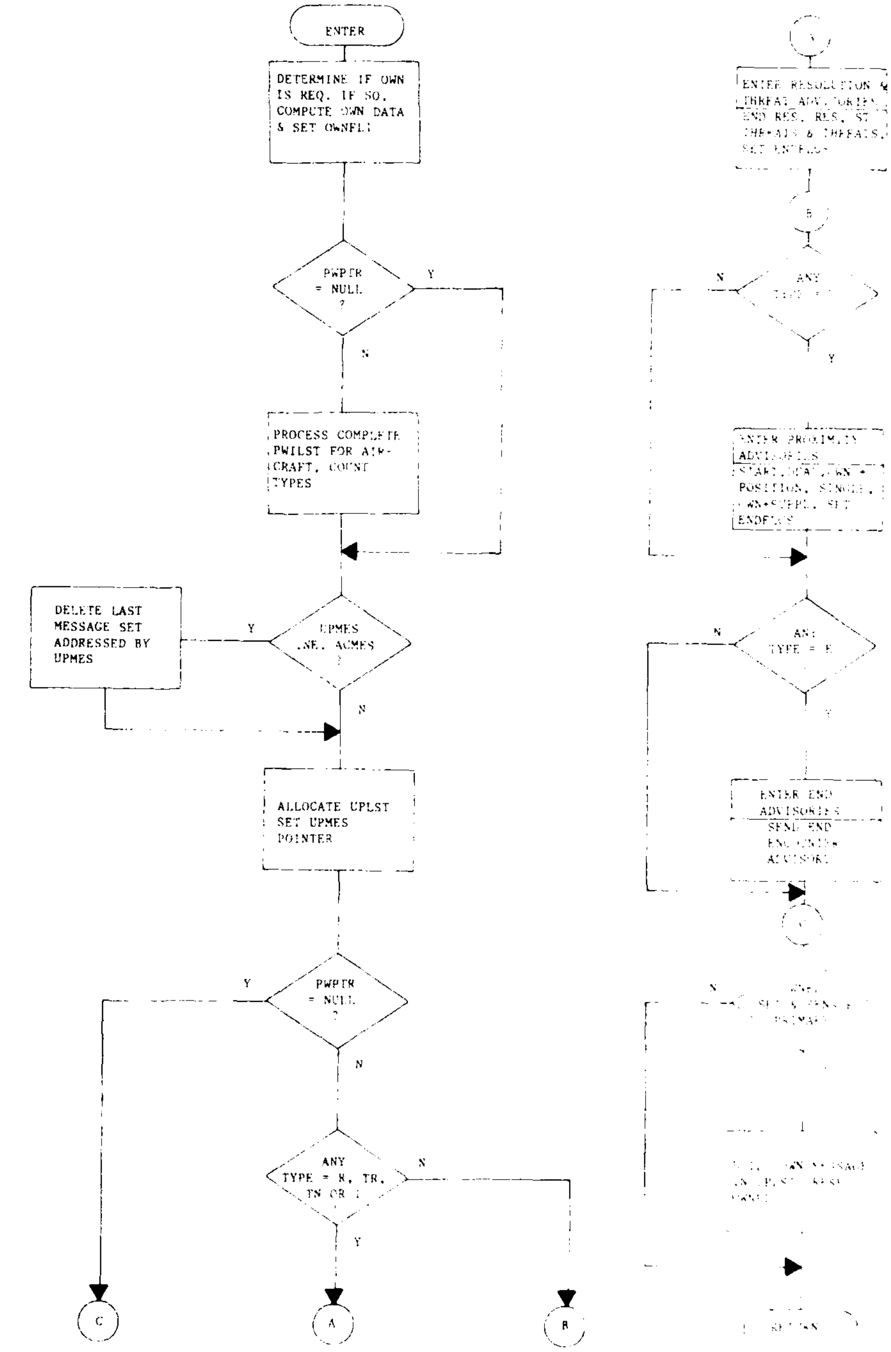


FIGURE 14-8
MESSAGE CONSTRUCTION ROUTINE

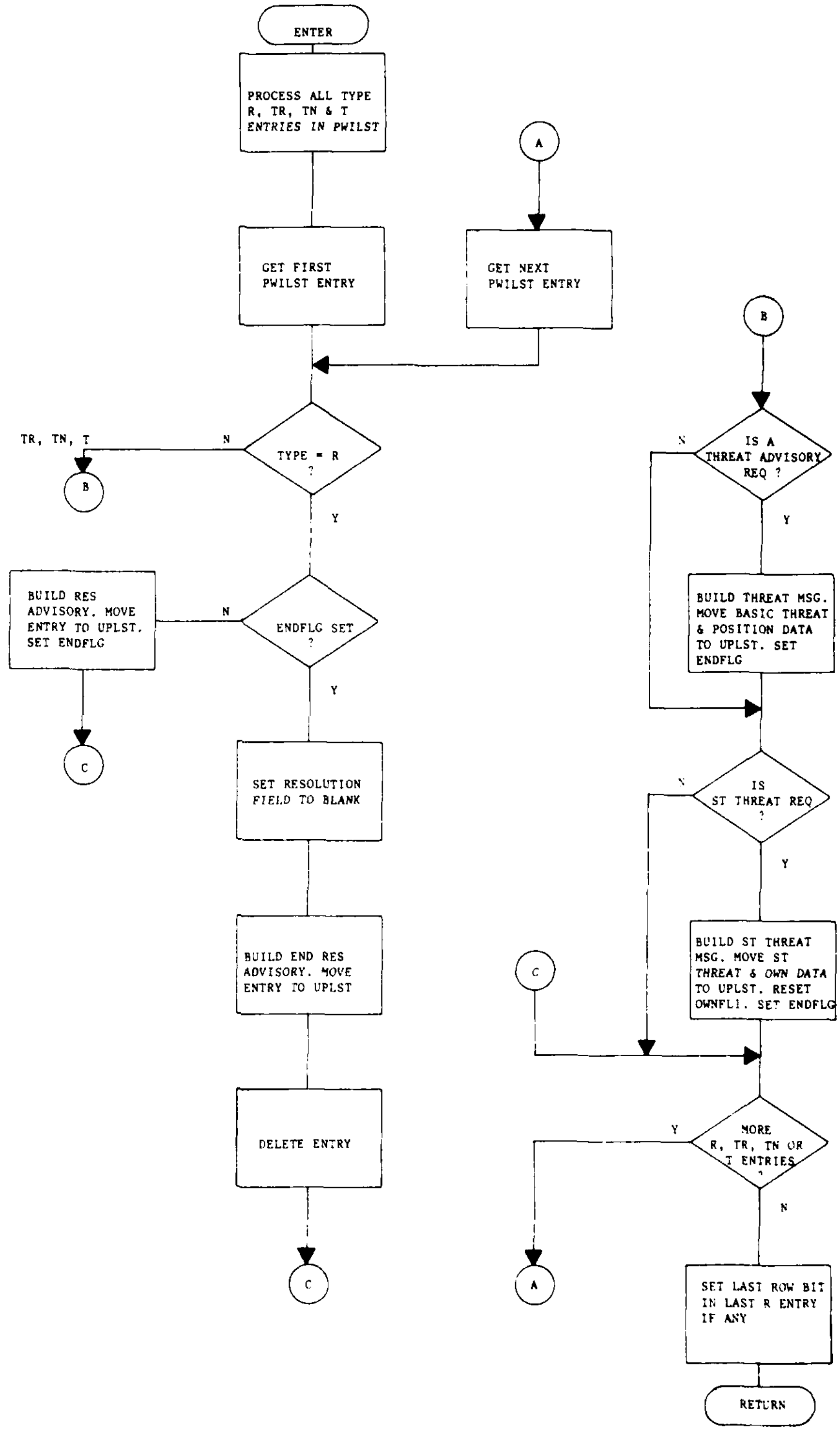


FIGURE 14-9
ENTER RESOLUTION AND THREAT ADVISORIES ROUTINE

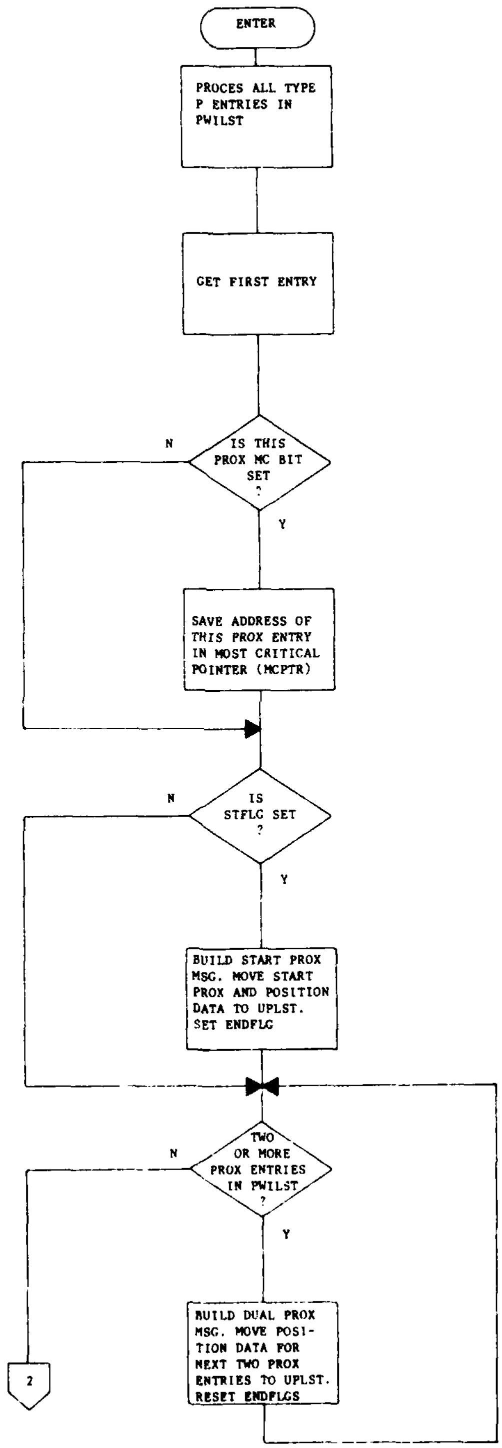


FIGURE 14-10
ENTER PROXIMITY ADVISORIES ROUTINE (Page 1 of 2)

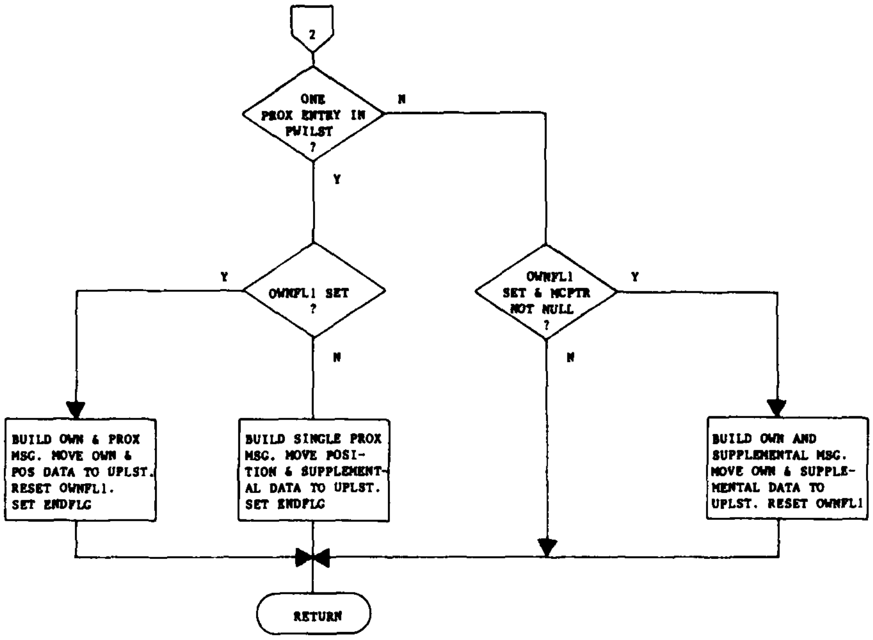


FIGURE 14-10
ENTER PROXIMITY ADVISORIES ROUTINE (Page 2 of 2)

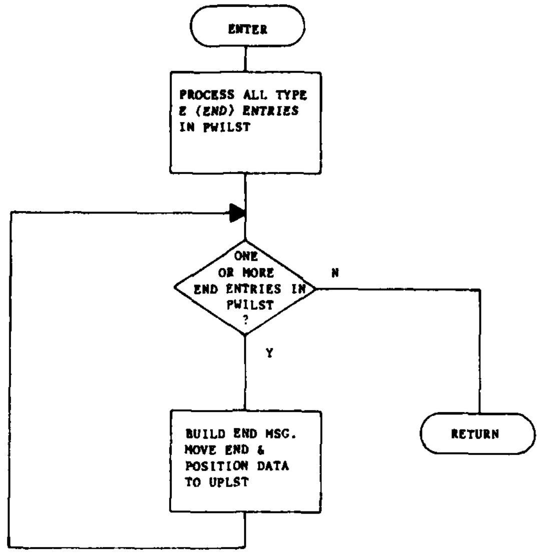


FIGURE 14-11
ENTER END ADVISORIES ROUTINE

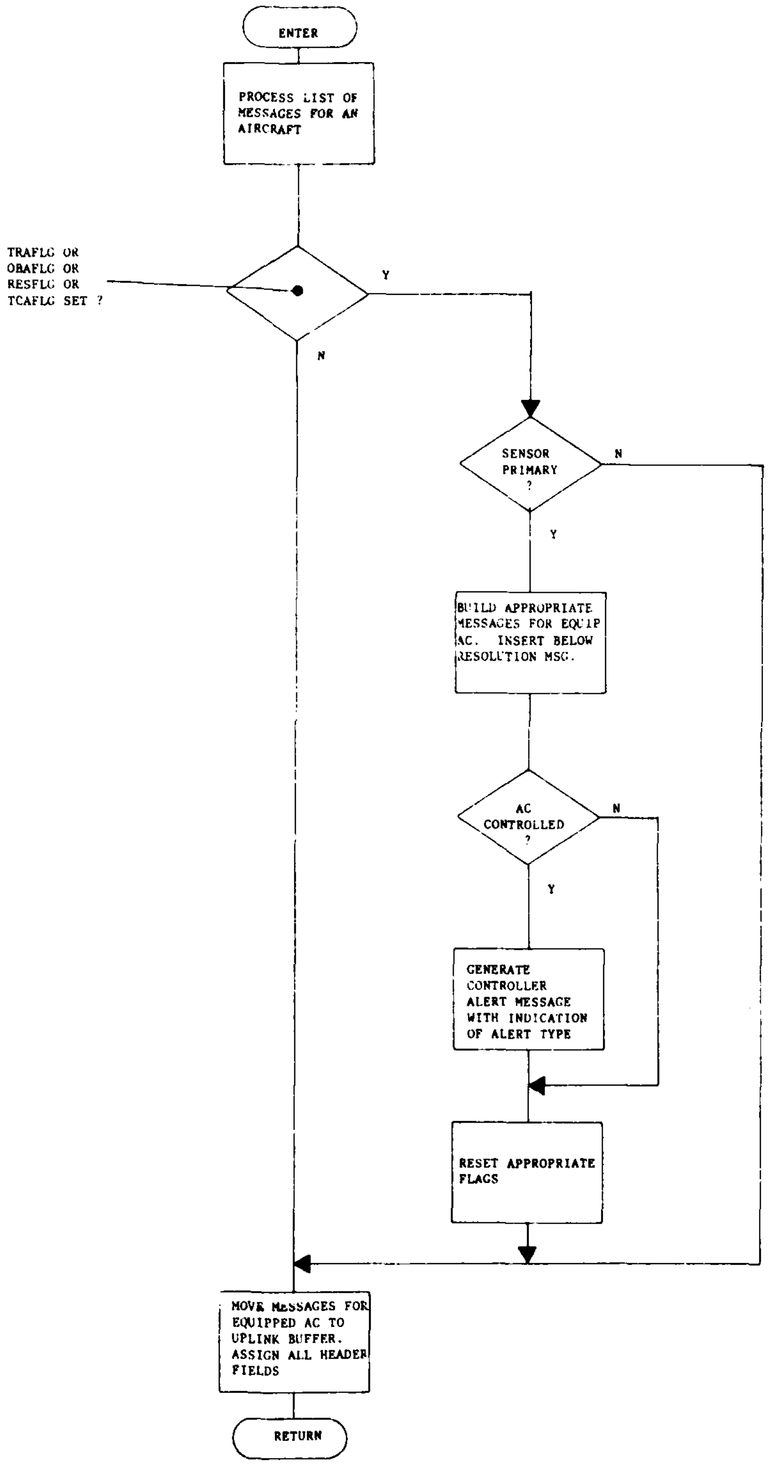


FIGURE 14-12
FINAL MESSAGE PROCESSING ROUTINE

15. FAILURE MODE OPERATION

Protection against numerous types of failures is incorporated in the ATARS system design. Specific features are provided to cope with the following ATARS-specific failures:

1. Failure to receive a target report from the local sensor.

2. False altitude or track association in target report from local sensor.

3. Failure to deliver traffic or resolution advisory by local sensor.

4. Incomplete CIR downlink report from local sensor.

5. ATARS selects a resolution advisory which is incompatible with an aircraft's exisiting resolution advisories.

6. Failure of a ground communication channel between sensors.

7. Where a ground communication channel is not provided, or has failed, ATARS selects resolution advisories, not knowing the pair of aircraft is already being resolved by another ATARS site.

8. Failure of the DABS sensor at a single site.

9. Failure of the ATARS function at a single site.

10. Catastrophic failure of an ATC facility.

Logic for items 8 and 9 is contained in this section. The features which accommodate the other items are found in other sections of this document. All the capabilities are discussed here to summarize the robust nature of the overall design.

15.1 Missing Target Report

If the local sensor misses a target report on an aircraft, it requests a report from an adjacent sensor. ATARS performs coordinate and time conversion for the remote report and uses it to update the track for the aircraft. If the aircraft is equipped with a CIR, ATARS requests a CIR report from the remote

sensor. Even if that sensor was not previously reading the aircraft's CIR, the remote sensor may do so by "borrowing" the local ATARS ID. This prevents confusion among ATARS sites as to the aircraft's location in an ATARS seam.

When a sensor detects an aircraft passing into its antenna's zenith cone ("cone of silence"), it requests an adjacent sensor to provide target reports continuously until told to stop. In a like manner, ATARS requests CIR reports from the adjacent sensor, for an equipped aircraft, to be provided until told to stop.

If no target report is obtained from any sensor (e.g., no adjacent sensor covered the aircraft's location or no ground communication channel is operating), ATARS coasts the track using its last estimates of position and velocity. Full conflict detection continues. If no report is received by a predetermined time, ATARS drops the track.

If a position report is received with altitude missing, the altitude estimate is coasted. If a target report is received but CIR data is missing, ATARS assumes the last known CIR contents are unchanged, rather than assuming an empty CIR.

15.2 Target Report Contains False Altitude or Track Association

ATARS maintains tracks on aircraft in its service area which are independent of DABS surveillance tracks. Since the requirements of a collision avoidance system differ from a surveillance system, ATARS uses its own criteria for establishing or dropping tracks.

ATARS performs a reasonability check on each altitude report. If unreasonable, the altitude report is ignored. If a falsely decoded altitude is sufficiently reasonable to be accepted, it is smoothed by the tracker and thus is unlikely to seriously affect ATARS service.

The requirements for starting a new track, especially for non-discrete beacon codes, ensures that phantom aircraft tracks are very unlikely.

15.3 Sensor Fails to Deliver Traffic or Resolution Advisory

Although the DABS data link is very reliable, the sensor may occasionally fail to deliver traffic or resolution advisories. When a target report was received, but part or all of the ATARS

messages were not delivered during the beam dwell, ATARS has good reason to believe that the aircraft is still visible to the sensor. ATARS simply computes updated advisories for the next scan. In the meantime, the avionics retains the existing advisories until they are updated, or until a time out several scans in length has expired. The avionics ignores any incomplete resolution uplinks that may have been delivered. When an ATARS uplink message was attempted and not even a target report was successfully achieved by the local sensor, ATARS immediately attempts to deliver its messages through one (and only one) adjacent connected sensor. The adjacent sensor borrows the local ATARS ID, regardless of whether or not its own ATARS is providing service to the aircraft. The DABS multi-link protocol may not be used for ATARS uplink messages.

15.4 Incomplete CIR Downlink Report

An incomplete CIR downlink report is ignored. If ground communication lines to adjacent sites are operating, the multi-site ground protocol provides complete current information regarding seam conflicts. A complete CIR downlink is very likely to be received on the next scan.

15.5 ATARS Selects Incompatible Resolution Advisory

ATARS resolution logic always selects new resolution advisories compatible with an aircraft's existing resolution advisories. However, if an existing advisory is not known to the ground, an incompatible (i.e., contradictory) sense advisory could be uplinked. This could happen if a BCAS outside ATARS coverage (called a "pop-up" threat) initiated resolution with the subject aircraft since the last CIR downlink; or if another ATARS site, unconnected by a ground communications line, resolved another conflict since the last CIR downlink.

Any incompatible advisory is ignored by the ATARS avionics. The CIR performs a compatibility check for every uplinked advisory. If multiple advisories are being uplinked, all compatible advisories will be accepted even if others are incompatible and ignored. ATARS reads down a copy of the CIR contents as they existed at the time the CIR was first accessed (typically near the beginning of the current beam dwell). ATARS duplicates the avionics' compatibility logic to immediately determine whether each of its uplink advisories will be accepted. For any which are found incompatible, new advisories are recomputed for delivery the next scan, taking account of the updated copy of the CIR contents.

15.6 Failure of Ground Communications Channel

A ground communications channel between sensors is not a critical element for ATARS operation. Where a network of more than two DABS sensors exists, the loss of a ground channel prompts DABS network management to establish alternate message paths. Whenever this succeeds, the ground channel failure is transparent to ATARS.

When ATARS becomes unconnected to a neighbor, some degradation of service will occur, since remote reports, cone of silence coverage, and remote uplink become unavailable. However, the majority of service, including multi-site coordination of conflict resolution, continues unaffected. The CIR is used as the coordinating device for all resolution, and responsibility is unchanged.

15.7 Resolution Duplicating That Provided by Another Site

Whenever a ground communication channel is available, positive coordination between sites assumes that only one site at a time issues resolution advisories to a particular pair of aircraft. However, when no channel is provided, or when the channel has failed, such duplicate service may be attempted in certain situations. This would happen when a DABS-ATCRBS pair in an ATARS seam comes into conflict since the last CIR downlink; or when a DABS-DABS pair flies into an ATARS seam and site responsibility changes just before the conflict begins, and one site has been unable to read down the CIR site ID bits for at least one scan since they changed. The latter situation is a compound event of low probability.

To prevent duplicate resolution of a pair, since the two sites might select incompatible resolution, every CIR "row" (stored resolution advisory) is marked with the ID of the ATARS site that created it. No other site may change the row. If the aircraft leaves the original site's service area, the site sends a message to release its control of the row. If the ground-air link is lost, the row is deleted by the avionics time out feature and a different site may then resolve the pair.

15.8 Failure of the DABS Sensor

The DABS sensor is complex and may fail in a variety of ways, many of which are beyond the scope of this document. Any failure which causes the local ATARS function to fail is treated in Section 15.9.

If only the surveillance function or RF channel fails, so that ATARS continues to operate, data from remote sensors may be used as described in Sections 15.1, 15.3, and 15.4. In this case, ATARS attempts to provide service in its usual area, but is limited to servicing those aircraft seen by adjacent connected sensors.

15.9 Failure of ATARS Function

Any network of neighboring DABS sensors may take advantage of overlapping DABS coverage for the purpose of allocating replacement coverage for a failed ATARS site. This section discusses the means for recognition of a failed ATARS and the action to be taken.

15.9.1 Status Message Processing and Backup Mode

Each DABS sensor contains a performance monitoring function. Once per scan, the sensor sends sensor status and ATARS Status Messages to all adjacent sensors. ATARS is only interested in the status ("operational" or "failed") of the ATARS function of each of its neighbors. ATARS periodically performs the Function Status Message Processing Routine shown in Figure 15-1. This routine examines all remote ATARS status message which have been queued since the last execution of the routine. The routine maintains a Function Failure Flag (FFF) indicating the status of each remote ATARS. However, the logic only accommodates a single remote ATARS failure.

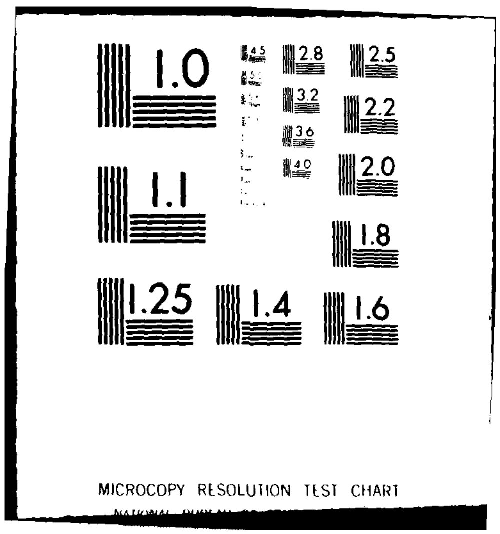
Upon recognizing the first such failure, the Backup Mode Initiation Routine (Figure 15-2) is called. This routine replaces the ATARS service zone mask with the backup service zone mask corresponding to the failed ATARS. If own ATARS is due to become the "master" site for this failure (see Section 15.9.2), a substitute priority table is invoked. This replaces the normal table used to determine whether own ATARS is the site responsible for a pair of aircraft (see Section 7.2). When the substitute table is used, both the failed site's ID and own-site's usual ID are considered to be "own" ID. This is also true in all other places in the algorithms which test for "GEOG contains own ID" or "ATSID equal to own ID." ATARS does not assume a remote ATARS failure when a communication line fails.

When an "operational status" message is received from a previously failed ATARS, the Backup Mode Termination Routine is executed. This routine merely reinstates the normal service area, resets the master flag, and reinstates the normal priority

AD-A094 195 MITRE CORP MCLEAN VA METREK DIV F/G 1/5
AUTOMATIC TRAFFIC ADVISORY AND RESOLUTION SERVICE (ATARS) MULTI--ETC(U)
OCT 80 R H LENTZ, W D LOVE, N S MALTHOUSE DOT-FA80WA-4370
UNCLASSIFIED MTR-80W00100-REV-1 FAA-RD-80-3-REV-1 NL

6 of 6
AD A
094 195

END
DATE
FILMED
2-81
DTIC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART

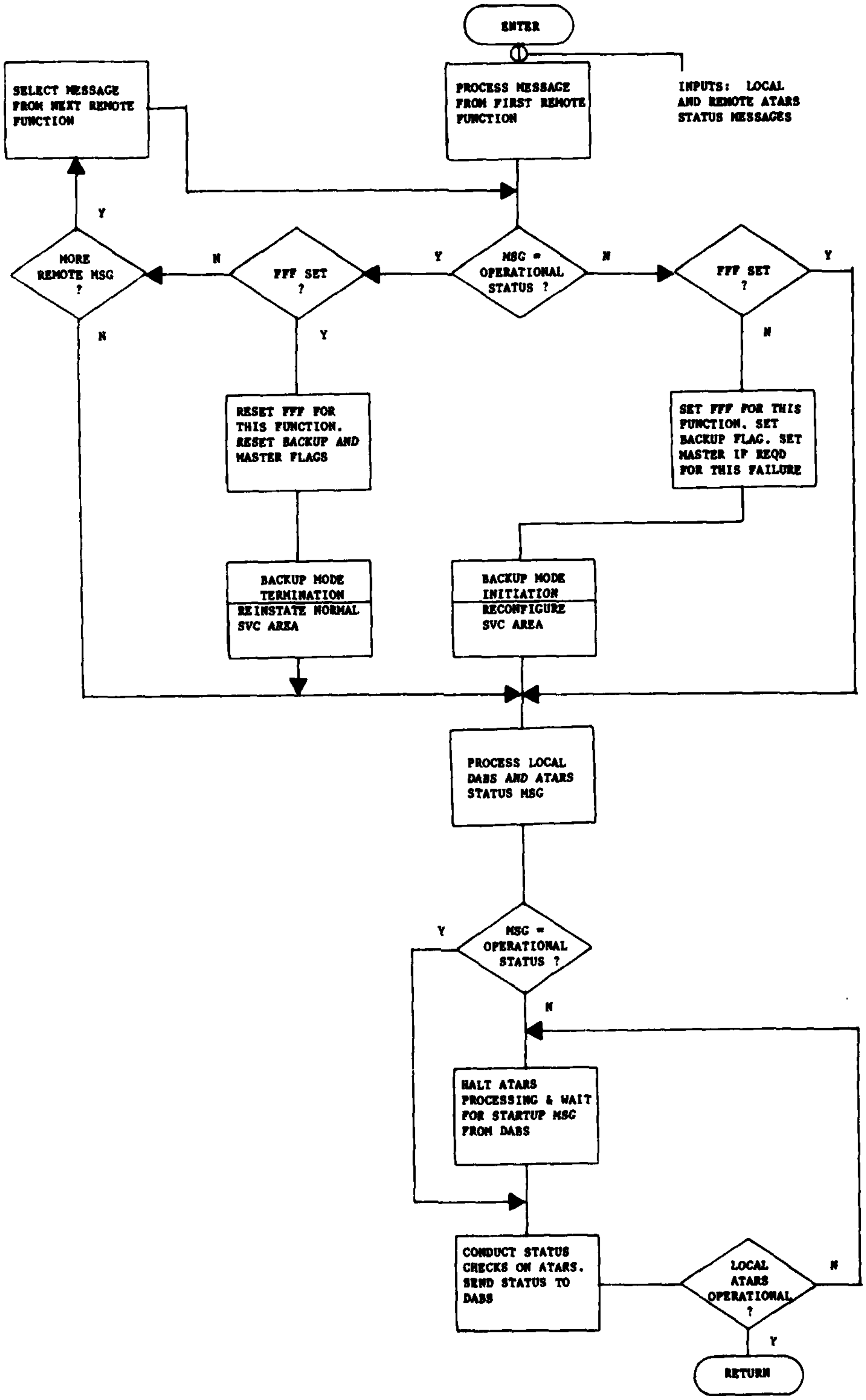


FIGURE 15-1
FUNCTION STATUS MESSAGE PROCESSING ROUTINE

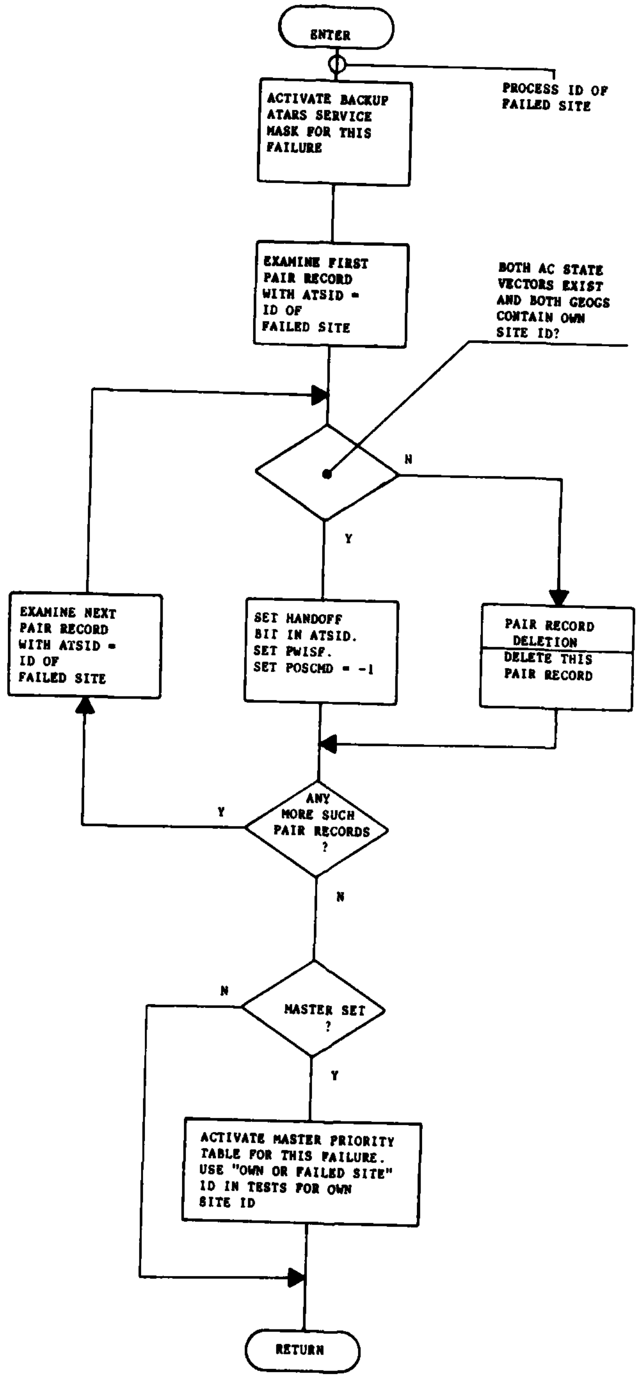


FIGURE 15-2
BACKUP MODE INITIATION ROUTINE

table. It is not necessary to send conflict tables to the recovered site, since that site should be able to immediately read down aircraft CIR's, and may request conflict tables from its neighbors over ground lines. When the (smaller) normal service mask is reinstated, aircraft outside this mask will be dropped by the ATARS tracker in the normal way, just as if they had flown out of the service zone.

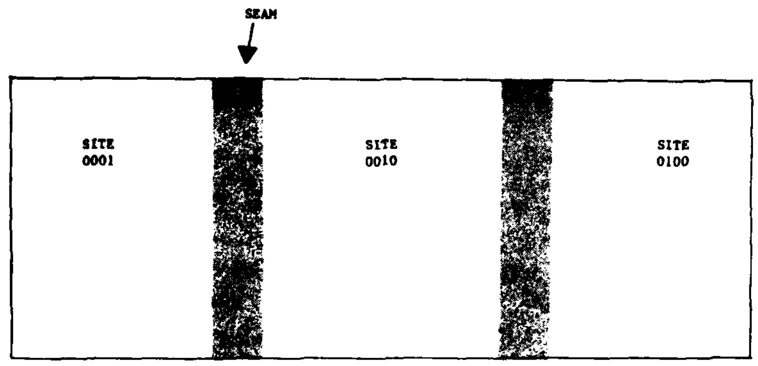
15.9.2 Backup ATARS Service Areas

In a region having several DABS sensors located within reasonable proximity, some flexibility may exist in drawing the ATARS map boundaries. The choice of boundaries will take into account geographical coverage, terrain features and the expected traffic load for the sensors. Upon the failure of one ATARS site, other sensors with overlapping coverage may be capable of replacing the failed ATARS. If the failed site was serving a large load of traffic, no single neighbor may have sufficient capacity to absorb it all. Therefore, a better strategy, where geographic coverage and terrain features permit, is to divide the failed site's service area among several neighbors.

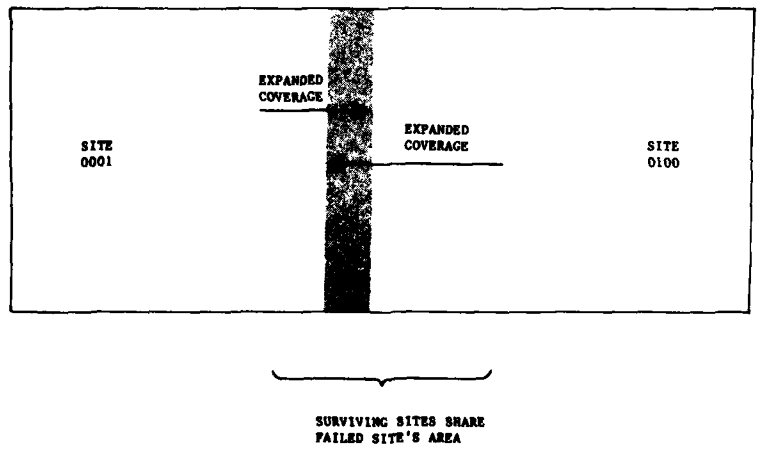
An example of this operation is depicted in Figure 15-3. Here, when the site with ID 0010 fails, its two neighbors each expand their coverage and share the failed site's area. The two surviving sites' maps should provide an overlap (seam) of the usual width. In this case, no "master" site or "center" zone (see below) is required. Both surviving sites operate normally, and treat newly acquired aircraft in their expanded service areas in the same manner as any aircraft which has just entered the normal service area. Any of these aircraft having CIR rows created by the failed site will soon have them released by the avionics time out. This is likely to happen even before the surviving site has established its new ATARS track on the aircraft. Thus no special measures are required.

The surviving sites may not be connected with ground communications lines. In this case, all coordination is performed through the transponders using the CIR features, as explained in Sections 12.2 and 15.6.

In certain configurations of ATARS sites, the simple procedure described above cannot be used. Since only four distinct ATARS ID's are assigned, the failure of an ATARS may cause two sites assigned the same ID to become adjacent, if the most desirable backup service map were implemented. Since the multi-site protocol does not permit this condition, several alternatives are available. Using another neighbor to cover the failed area



A) COVERAGE WITH ALL 3 SITES OPERATING



B) COVERAGE WHEN SITE 0010 FAILS

FIGURE 15-3
EXAMPLE OF AREA WHERE CENTER ZONE NOT USED FOR BACKUP COVERAGE

may be feasible, but geographic considerations may prohibit this choice. Leaving a coverage gap without ATARS is very undesirable. The solution implemented in this design is to designate one of the surviving sites as the "master" site. This should be the site with the best geographical coverage of the part of the failed area that separates the two sites having the same ATARS ID. The "master" site then continues to serve its own ATARS area using its own ID, and also serves a small "center" zone within the failed site's area, borrowing the failed site's ATARS ID to send to aircraft in this area. This is illustrated in Figure 15-4. The "center" zone should be made small, so all sites may use their own ID in as large an area as possible, but sites with like ATARS ID's must be separated by more than the usual seam width.

The "master" site performs an extra masking (in this backup mode) to decide which of the aircraft in its expanded coverage are in the "center" zone and thus are to receive the failed site's ID. The "master" site still uses its own sensor to serve both of its areas, sending different ATARS ID's to aircraft according to their location. The "center" zone is mapped to have the usual overlap (seam) with all of its neighboring sites except the "master" site. No overlap is provided between master's own area and its "center" zone. The master ATARS keeps aircraft in both of its areas in the same data base, and is able to treat the boundary between its two areas as "soft". This means that if an aircraft receiving resolution crosses this boundary, the "master" site may continue to send resolution advisories without changing the site ID for that aircraft.

15.10 Failure of the ATC Facility

ATARS normally serves controlled aircraft only as a backup to ATC. When aircraft come into conflict in sufficiently hazardous situations, ATARS issues traffic and resolution advisories. This action is performed routinely, and in the event of a catastrophic ATC failure, ATARS continues to provide full service.

It is possible to implement a backup area type map which would be invoked upon receipt of an ATC Failure Message. No specific logic for this feature is provided.

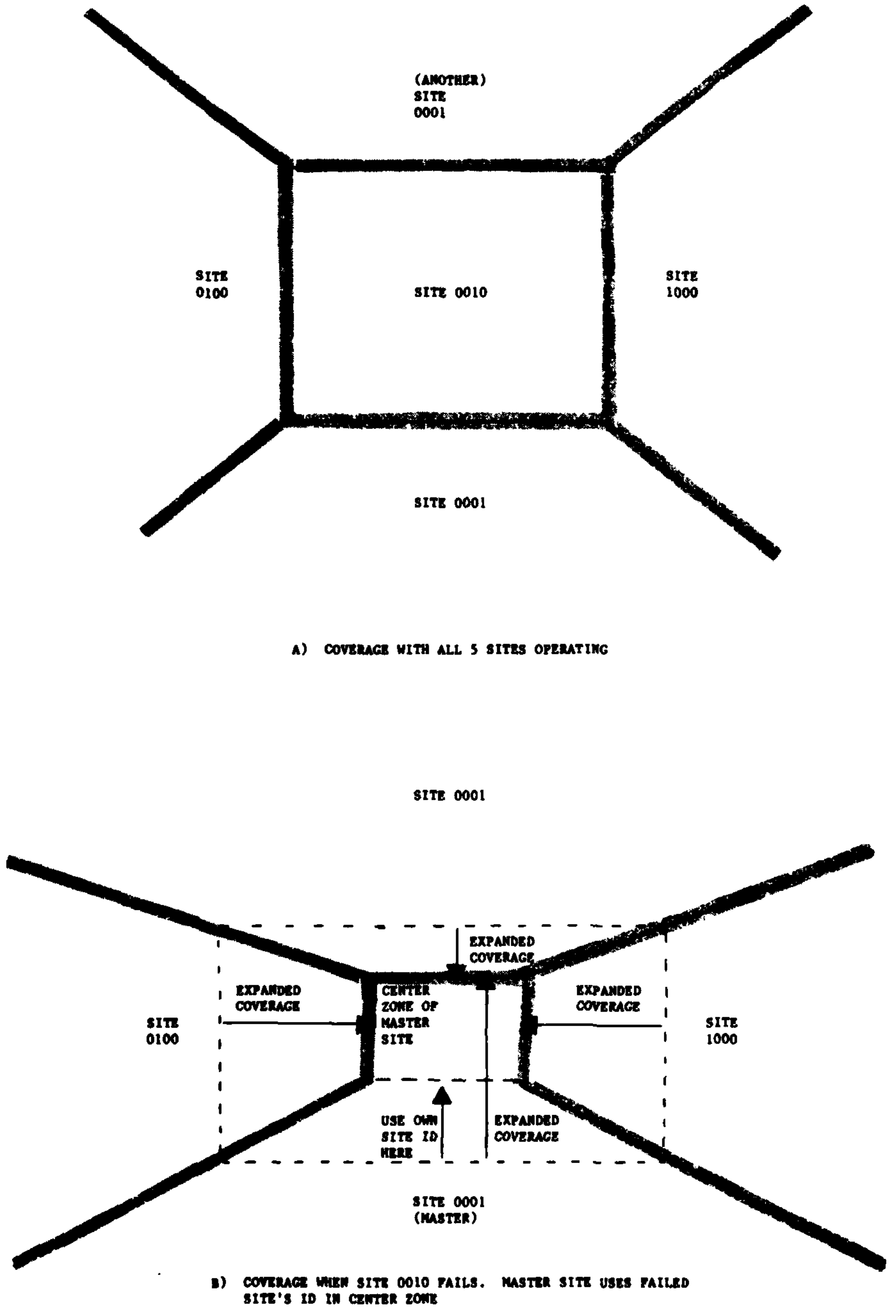


FIGURE 15-4
EXAMPLE OF AREA WHERE CENTER ZONE IS USED FOR BACKUP COVERAGE

APPENDIX A

SYSTEM PARAMETERS

TABLE A-1

SYSTEM PARAMETERS (ALPHABETICAL ORDER)

This table identifies system parameters and briefly describes their utilization. Nominal values are given to assist in understanding the algorithms. The performing organization is responsible for maintaining a consistent set of units within the particular system being implemented. Variations of these parameters will be made in the appropriate test plans.

* These thresholds are to be applied directly to the altitude replies of the aircraft when the replies are expressed in feet. Neither the thresholds nor the replies from the aircraft are to be adjusted for local barometric pressure.

** This parameter can be changed via an external device in real-time. This threshold is to be applied directly to the altitude replies of the aircraft when the replies are expressed in feet.

SYMBOL	UTILIZATION	NOMINAL VALUE
ABETA	Smoothing constant used in azimuth rate estimation.	.5
ACCELC	Upward acceleration modeled in response to a vertical resolution advisory.	4 ft/s^2
ACCELD	Downward acceleration modeled in response to a vertical resolution advisory.	8 ft/s^2
ACONTH	Vertical range used in calculation of TCONV. See PREPAR.	See Table 7-11
ADET	Sets miss distance threshold (DSQ) for modified tau test.	92.5 sec^2
AF	Immediate altitude threshold for resolution advisory See SCMDF.	See Table 7-11 and Table 10-12
AFCON	Immediate altitude threshold for controller alert. See SCAFLG.	See Table 7-11
AFDET	Immediate altitude threshold for Detect Task prefiltering.	See Table 7-11
AFIFR	Immediate altitude threshold for controlled aircraft threat advisory. See SFPIF.	See Table 7-11
AFPWI	Immediate altitude threshold for uncontrolled aircraft threat advisory. See SFPWF.	See Table 7-11
AHI	Altitude threshold for search of X-list with aircraft from EX-list in coarse screening.	12,000 ft*

TABLE A-1

SYSTEM PARAMETERS
(Continued)

AIFR	Immediate altitude threshold for a controlled aircraft resolution advisory set. See SIFRF.	See Table 7-11
ALO	Altitude boundary for EX-list and X-list in coarse screening.	10,000 ft*
ALPC	Lower limit of positive controlled airspace used to select positive resolution advisory altitude threshold.	18,000 ft*
ALTDP	Projection altitude used in resolution advisory vertical divergence logic. See SCMDF and SIFRF.	See Table 7-11
ALUH	Lower limit of ultra high altitude airspace used to select positive resolution advisory altitude threshold.	29,000 ft*
ASEP	Positive resolution advisory immediate altitude threshold (ASEPH, ASEPIL, ASEPL, ASEPU).	___________
ASEPH	High altitude positive resolution advisory threshold.	670 ft
ASEPIL	Low altitude positive resolution advisory threshold for controlled/uncontrolled and controlled/controlled.	375 ft
ASEPL	Low altitude positive resolution advisory threshold for uncontrolled pair.	470 ft
ASEPU	Ultra high altitude positive resolution advisory threshold.	770 ft
ASEPV	Altitude threshold for giving VPOS to slow aircraft.	350 ft
ATERN	Altitude threshold below which a descend resolution advisory is not used.	1000 ft**
BANKA	Bank angle used to model turn in Master Resolution Task.	20°
BDET	Sets miss distance threshold (DSQ) for modified tau test.	.107 nmi^2
BDROP	Number of scans ATARS must wait after the disappearance of BCAS resolution advisories for a conflict before the pair.record can be dropped.	2

TABLE A-1

SYSTEM PARAMETERS
(Continued)

CAMTM	Time interval between requests for a controller alert advisory to delete advisory (= 2 scans).	9.4 sec
CAMR2	Square of range threshold for maneuvering aircraft conflict logic. See CAMAN.	3.25 nmi
CAMA	Altitude separation threshold for maneuvering aircraft conflict alert logic. See CAMAN.	1000 ft
CAMVSQ	Square of aircraft velocity threshold for maneuvering aircraft conflict alert logic. See CAMAN.	325 kts^2
CAMCP2	Square of cosine of the angle between aircraft velocities for determing parallelness. See CAMAN.	.981
CAMSB2	Square of sine of the angle between subject aircraft velocity and target aircraft relative position vectors, which determines parallel offset or parallel in trail condition. See CAMAN.	.117
COAA2	Cosine squared of approach angle threshold for determining final approach status. See SATAZ.	.9698
COSP2	Square of the cosine of the angle between aircraft velocities for determining parallelness. See SMTTF.	.981
DELAY	Predicted uplink delay plus pilot's delay in response to resolution advisories.	11 sec
DELTA	Extra heading correction in tracking when turn is sensed on two consecutive updates.	15 degrees
DOTTH	Divergence threshold at which resolution advisories are inhibited.	.00278 $\frac{nmi^2}{sec}$ (10 nmi-kts)
FESTAB	Firmness value used to determine if track is qualified for ATARS processing.	6

TABLE A-1

SYSTEM PARAMETERS
(Continued)

HMIN	Miniumum time threshold in horizontal direction for bypassing 2/3 sliding window maneuver logic. See SCMDF and SIFRF.	20 sec
HUBRAD	Radius of hub processing area.	10 nmi
HZONE	Altitude used to separate high from low geographical zone.	18,000 ft*
LRGTAU	Value of horizontal tau which must be larger than any value which can be computed in the Detect Task. This value is assigned to horizontal tau in the Compute Threat Segment Data Routine when aircraft are diverging.	999 sec
MCTA	Number of scans out of NCTA scans for which the CAFLG must be set in order to generate a Controller Alert Message.	3
MDCON2	Square of miss distance threshold for controller alert. See SCAFLG.	See Table 7-11
MDFPI2	Square of miss distance threshold for issuing a threat advisory to controlled aircraft. See SFPIF.	See Table 7-1'
MDFPW2	Square of miss distance threshold for issuing a threat advisory to uncontrolled aircraft. See SFPWF.	See Table 7-11
MDHSQ	Square of horizontal miss distance at which resolution strategy changes.	0.083 nmi^2 $(1750\ ft)^2$
MDTHSQ	Square of horizontal miss distance threshold for giving positive resolution advisories.	.25 nmi^2
MRATE	Minimum vertical rate required to choose Vertical Speed Limit (VSL) resolution advisories.	400 ft/min
MTLL	Lower limit on maneuver time in PSEP calculation.	30 sec
MTTA	Altitude separation threshold for maneuvering target threat logic. See SMTTF.	1000 ft
MTTR2	Square of range threshold for maneuvering target threat logic. See SMTTF.	3.25 nmi^2

TABLE A-1

SYSTEM PARAMETERS
(Continued)

MTTRM2	Check against range to prevent divide by zero. See SMTTF.	.00244 nmi^2
MTTSB2	Threshold for square of sine of angle between subject aircraft velocity and target aircraft relative position vectors, which determines parallel offset or parallel in trail status. See SMTTF.	.117
MTTVR2	Square of relative velocity threshold for determining slow-closing status. See SMTTF.	1600 kts^2
MTTVSQ	Square of aircraft velocity threshold for maneuvering target threat filtering. See SMTTF.	325 kts^2
MTUL	Upper limit on maneuver time in PSEP calculation	120 sec
NCTA	Window for generation of Controller Alert Message.	5
OBALT	Altitude limit above which the obstacle detection logic is not executed.	3000 ft*
OBXCK	X distance value for obstacle proximity check	2000 ft
OBYCK	Y distance value for obstacle proximity check	2000 ft
OBZCK	Z distance value for obstacle proximity check	500 ft
OGHDIF	Minimum absolute value of difference between (last own ground track heading plus turn rate X delta time) and (current own ground track heading) to generate new Own Message.	12°
PWIZ	Altitude difference determining whether two aircraft are co-altitude.	500 ft
RCMD2	Square of horizontal immediate range for resolution advisory set. See SCMDF.	See Table 7-11 and Table 10-12
RCONTH	Horizontal range used in calculation of TCONH. See PREPAR.	See Table 7-11

TABLE A-1

SYSTEM PARAMETERS
(Continued)

RCON2	Square of horizontal immediate range for controller alert. See SCAFLG.	See Table 7-11
RDET	Immediate range threshold for Detect Task prefiltering	See Table 7-11
RDIST	Range from radar used to separate area types 3 and 4.	90 nmi
RDISTR	Distance from the radar where range-azimuth data becomes unreliable.	90 nmi
RFIFR2	Square of horizontal immediate range for a threat advisory to controlled aircraft.	See Table 7-11
RFPWI2	Square of horizontal immediate range for a threat advisory to uncontrolled aircraft. See SFPWF.	See Table 7-11
RIFR2	Square of horizontal immediate range for resolution advisory to controlled aircraft.	See Table 7-11
RMAX	Maximum distance traveled by an aircraft over the longest appropriate system look-ahead time (RMAXI, RMAXH, RMAXV).	________
RMAXH	Maximum distance traveled by intruding aircraft in EX-list coarse screen filter.	20.0 nmi
RMAXI	Maximum distance traveled by intruding aircraft in coarse screening filter for a controlled subject aircraft.	8.0 nmi
RMAXV	Maximum distance traveled by intruding aircraft in coarse screening filter for an uncontrolled subject aircraft.	5.0 nmi
RPMIN	The square of the minimum range at which a proximity advisory is given.	4.0 nmi^2
RPWI	Maximum effective proximity advisory range.	4.0 nmi
SCANTM	Nominal time interval for one radar scan.	4.7 sec
SEP1	3-D slant range used in resolution to evaluate resolution advisories.	.0271 nmi^2 $(1000\ ft)^2$

TABLE A-1

SYSTEM PARAMETERS
(Continued)

SEP2	3-D slant range used in resolution to evaluate resolution advisories.	.0531 nmi^2 $(1400\ ft)^2$
SPLO2	Square of maximum assumed speed for aircraft below 10,000 ft. MSL.	.004444 nmi^2/sec^2 $(240\ kts)^2$
TAF	Current altitude threshold used in resolution.	1000 ft
TCMDH	Horizontal tau threshold for resolution advisory set. See SCMDF.	See Table 7-11 and Table 10-12
TCMDV	Vertical tau threshold for resolution advisory set. See SCMDF.	See Table 7-11 and Table 10-12
TCONH	Horizontal tau threshold for controller alert. See SCAFLG.	See Table 7-11
TCONV	Vertical tau threshold for controller alert. See SCAFLG.	See Table 7-11
TDDS	Scan time correction threshold.	.1 sec
TDP	Projection time in resolution advisory vertical divergence logic. See SCMDF and SIFRF.	See Table 7-11
TDROP	Time interval without a horizontal reply to drop a track.	19 sec
TFIFRH	Horizontal tau threshold for a threat advisory to a controlled aircraft. See SFPIF.	See Table 7-11
TFIFRV	Vertical tau threshold for a threat advisory to a controlled aircraft. See SFPIF.	See Table 7-11
TFPWIH	Horizontal tau threshold for a threat advisory to an uncontrolled aircraft. See SFPWF.	See Table 7-11
TFPWIV	Vertical tau threshold for a threat advisory to an uncontrolled aircraft. See SFPWF.	See Table 7-11
THMS	Rho, Theta measurement time interval required to zero horizontal maneuver status.	5 sec

TABLE A-1

SYSTEM PARAMETERS
(Continued)

THVDIF	Minimum absolute value of difference between last delivered threat velocity and current threat velocity required in test for start threat advisory.	20 kts
THVPER	Minimum percentage difference between last delivered threat velocity and current threat velocity required in test for start threat advisory.	.10
TIFRH	Horizontal tau threshold for a controlled aircraft resolution advisory set. See SIFRF.	See Table 7-11
TIFRV	Vertical tau threshold for a controlled aircraft resolution advisory set. See SIFRF.	See Table 7-11
TIMINT	Time value equal to one-half of a radar scan.	2.35 sec
TLA	Largest appropriate look-ahead time (TLI, TLV).	_________
TLD	Total look-ahead time used in Domino Coarse Screen Routine.	_________
TLI	Longest look-ahead time for a controlled aircraft in the coarse screening filter.	120 sec
TLPSQ	Square of proximity advisory time parameter.	900 sec^2
TLV	Longest look-ahead time for an uncontrolled aircraft in the coarse screening filter.	75 sec
TMZMAX	Maximum time since last altitude report for track to qualify for ATARS processing.	15 sec
TRALT	Altitude above which terrain avoidance logic is not executed.	5000 ft*
TRECOM	Time delay before test of recomputation of horizontal resolution advisories.	27 sec
TRHTM	Horizontal projection time for terrain bin checks.	60 sec
TRKS1	Strong turn sensing parameter (range factor).	.9
TRKS2	Strong turn sensing parameter (azimuth factor).	.9

TABLE A-1

SYSTEM PARAMETERS
(Continued)

TRKW1	Weak turn sensing parameter (range factor).	.5
TRKW2	Weak turn sensing parameter (azimuth factor).	0
TSCMD	Minimum duration of positive resolution advisories.	7 sec
TTH	Extra heading correction in tracking when turn is sensed in two consecutive updates.	40 degrees
TTM	Used to determine resolution advisory time threshold delta in resolution.	2
TURNA	Angle the aircraft is expected to turn through in response to horizontal resolution advisories.	180°
TV1	Look-ahead time threshold for altitude crossover.	8 sec
TV2	Look-ahead time threshold to allow level off.	16 sec
TVDP	Tau threshold for resolution advisory vertical divergence logic. See SCMDF and SIFRF.	See Table 7-11
TWARN	Warning time used in calculation of TCONV and TCONH.	See Table 7-11
TXTH1	The lower limit for the track crossing angle at which the resolution strategy changes.	60°
TXTH2	The upper limit for the track crossing angle at which the resolution strategy changes.	120°
V500	Threshold for 500 ft/min VSL resolution advisory.	8.33 ft/sec
V1000	Threshold for 1000 ft/min VSL resolution advisory.	16.67 ft/sec
V2000	Threshold for 2000 ft/min VSL resolution advisory.	33.33 ft/sec
VFACTR	Vertical factor used for weighting vertical separation relative to horizontal.	5.0
VFAST	Speed threshold used for giving vertical resolution advisories.	.0025 nmi^2/sec^2 $(180\ kts)^2$

TABLE A-1

SYSTEM PARAMETERS
(Continued)

VMDTH	Square of relative horizontal velocity threshold for computing miss distance.	100 kts^2
VMIN	Minimum time threshold in vertical direction for by passing 2/3 sliding window to maneuver logic. See SCMDF and SIFRF.	20 sec
VP1	Altitude proximity for generation of a proximity advisory.	2000 ft
VPCS	Vertical proximity test limit used in coarse screening filter.	2000 ft
VRATC	Squared speed ratio for giving the controlled aircraft resolution advisories at the same time as uncontrolled, when the controlled aircraft is much faster than the uncontrolled.	2.25
VRATIO	Squared speed ratio threshold for giving double resolution advisories when a fast unequipped aircraft is conflicting with a slow equipped aircraft.	2.25
VRATTH	Squared speed ratio threshold for determining look-ahead time in unequipped/equipped encounters.	2.25
VRZCON	Relative speed threshold used to test for vertical slow closing or divergence.	-300 fpm
VRZTH	Threshold to prevent division by zero in computation of vertical TAU.	15 ft/min
VSLOW	Speed threshold used for giving horizontal resolution advisory.	.00111 nmi^2/sec^2 $(120\ kts)^2$
VTHSQ	Square of speed threshold used to determine if aircraft is fast or slow.	.00174 nmi^2/sec^2 $(150\ kts)^2$
VWEGHT	Vertical weight for computing 3-D weighted slant range.	5.0
WAC1	Range weighting factor for ATCRBS correlation.	40 nmi^{-2}
WAC2	Range rate weighting factor for ATCRBS correlation.	1000 sec^2/nmi^2

TABLE A-1

SYSTEM PARAMETERS
(Continued)

WAC3	Bearing weighting factor for ATCRBS correlation.	.001 deg^{-2}
WAC4	Bearing rate weighting factor for ATCRBS correlation.	.01 sec^2/deg^2
WAC5	Altitude weighting factor for ATCRBS correlation.	.000025 ft^{-2}
WAC6	Altitude weighting factor for ATCRBS correlation.	.000025 sec^2/ft^2
XBNER	X distance value used to determine if Y-line cross is near an adjacent bin.	1 nmi
XCORR	X and Y correlation limit for ATCRBS correlation.	3000 ft
XSP	Spacing between signposts in the X-list.	5 nmi
YBNER	Y distance value used to determine if X-line cross is near an adjacent bin.	1 nmi
ZAFCON	Minimum altitude separation between aircraft when both are in zone 2. See CAFLG.	275 ft.
ZCORR	Z correlation limit for ATCRBS correlation.	300 ft
ZDDWNF	Used to model descent rate of fast aircraft in the separation matrix.	41.6 ft/sec
ZDDWNS	Used to model descent rate of slow aircraft in the separation matrix.	25.0 ft/sec
ZDTH	Vertical rate threshold to determine when an unequipped aircraft has a threatening rate and to determine when vertical negative resolution advisories are disruptive to an equipped aircraft.	6 ft/sec
ZDUPF	Used to model climb rate of fast aircraft in the separation matrix.	25.0 ft/sec
ZDUPS	Used to model climb rate of slow aircraft in the separation matrix.	8.3 ft/sec
ZFAST	Z velocity threshold for non-subject aircraft in coarse screening.	16.67 ft/sec

TABLE A-1

SYSTEM PARAMETERS
(Concluded)

ZHMNX, ZHMXX, ZHMNY, AHMXY,	Minimum and maximum X and Y respectively to form a rectangle to encompus all area types 1 and 2 for an airfield.	Site Adaptable
ZJMNX, ZJMXX, ZJMNY, ZJMXY,	Minimum and maximum X and Y respectively to form a rectangle to encompus all zone types 1 and 2 for an airfield.	Site Adaptable
ZNOM	Altitude used in slant range correction when no altitude measurement is available.	5000 ft
ZRCON2	Square of minimum range allowed between aircraft when both are in zone 2. See CAFLG.	.25 nmi^2
ZZONZ2	One half of type 2 final approach zone vertical extent.	200 ft

APPENDIX B

FLOW CHART ABBREVIATIONS

Abbreviation		Word
ABS	-	absolute value
AC, A/C	-	aircraft
ADJ	-	adjacent
ADV	-	advisory
ALT	-	altitude
ANT	-	antenna
AZIM	-	azimuth
CA	-	controller alert
CALC	-	calculate
CC	-	controlled/controlled
CK(S)	-	check(s)
COMP	-	compute
CONF	-	conflict
CONT, CONTR	-	controlled
COORD	-	coordinates
CORR	-	corresponding
CTE	-	conflict table entry
CT	-	conflict table
CU	-	controlled/uncontrolled
DET	-	determine
DIST	-	distance
DZB	-	diffraction zone bit
EQ, EQUIP	-	equipped
.EQ.	-	equal to
EST	-	estimate
EVAL	-	evaluation
EXT	-	external
.GE.	-	greater than or equal to
GRND	-	ground
.GT.	-	greater than
HOR, HORIZ	-	horizontal
ID	-	identification
IND	-	indicate
INIT	-	initialization
INT	-	internal, integer
.LE.	-	less than or equal to
.LT.	-	less than
MAX	-	maximum value
MC	-	most critical
MIN	-	minimum value, minute

FLOW CHART ABBREVIATIONS
(Continued)

Abbreviation		Word
MSG(S)	-	message(s)
N/A	-	not applicable
.NE.	-	not equal to
NEG	-	negative
NO(S)	-	number(s)
NORM	-	normal
POS	-	position, positive, position data
POT, POTENT	-	potential
PR	-	pair record
PRED, PREDICT	-	predicted, prediction
PROC	-	processing
PROX	-	proximate, proximity
PT	-	point
PTR, PTS	-	pointer(s)
RAD	-	radius
REC(S)	-	record(s)
REF	-	reference
REQ, REQD	-	required
RES	-	resolution
RES ADV(S)	-	resolution advisory(s) (this abbr. should not be confused with the data item RESADV)
RESTRICT	-	restricted
ROUT	-	routine
RPT	-	report
RQSTING	-	requesting
SCR	-	screen
SECT	-	sector
SEQ	-	sequence
SIGN	-	sign function
SP	-	signpost
SQRT	-	square root
SUBJ	-	subject
SUPPL	-	supplemental
SVC	-	service
THRES	-	thresholds
THRO	-	through
TRK	-	track
UNC, UNCONT, UNCONTR	-	uncontrolled
UNEQ, UNEQUIP	-	unequipped
UTM	-	universal transverse mercator coordinate system

<u>**FLOW CHART ABBREVIATIONS**</u>
(Concluded)

Abbreviation		Word
VAL	-	value
VEL	-	velocity
Z	-	aircraft altitude

APPENDIX C

REFERENCES

1. "Engineering Requirement for a Discrete Address Beacon System (DABS) Sensor," Federal Aviation Administration, FAA-ER-240-26A, April 1980.

2. J. Dieudonne, "ATARS: A Functional Description," The MITRE Corporation, McLean, Virginia, MTR-80W00101, (Federal Aviation Administration, FAA-RD-80-46), April 1980.

3. J. Dieudonne, R. Lautenschlager, "DABS/ATARS/ATC Operational Systems Description," The MITRE Corporation, McLean, Virginia, MTR-79W00436, (Federal Aviation Administration, FAA-RD-80-42), April 1980.

4. D. K. Miskill, B. T. Golden, T. H. Green, "Software Documentation Standards for Program Development," Federal Aviation Adminstration, FAA-SRDS-140-SDS-1, April 1975.

5. N. A. Broste, J. A. Grupe', A. L. McFarland, W. P. Niedringhaus, L. Zarrelli, A. D. Zeitlin, "Active Beacon Collision Avoidance System - Collision Avoidance Algorithms," The MITRE Corporation, McLean, Virginia, MTR-79W00110, Rev. 1, (Draft-May 1980).

6. N. E. Fredman, "A Study of ATARS Turn Sensing for Use in Resolution Evaluation," The MITRE Corporation, McLean, Virginia, MTR-80W00110, (Draft-May 1980).

7. "Minimum Safe Altitude Warning Design Data," Sperry Univac, St. Paul, Minnesota, PX-11325, Rev. B, March 1977.

8. J. DeMeo, "DABS/ATC Facility Surveillance and Communications Message Formats," Federal Aviation Administration, FAA-RD-80-14, ATC-33, April 1980.

9. E. Lucier, "ATARS Traffic Advisory Service," Federal Aviation Administration, FAA-RD-80-43, April 1980.

*U.S. GOVERNMENT PRINTING OFFICE:1980 722-097/340 1-3
#38430